University Microfilms
313 North 1st St
Ann Arbor Michigan

American
POTATO JOURNAL

Volume 37 *January 1960* *Number 1*

CONTENTS

Correction of leaf necrosis of potatoes with foliar and soil applications of potassium 1
WINSTON M. LAUGHLIN AND CURTIS H. DEARBORN

Potato spindle tuber in Eastern Canada 13
D. S. MACLACHLAN

Potato scab control on organic soils. I. Initial response to PCNB 18
H. T. ERICKSON

The effect of time of planting on occurrence of internal brown spot in the potato variety Arran Banner in Lebanon 23
A. A. AHMADI, H. MOBARAK, AND JOHN OSGUTHORPE

The effect of harvest date and rate of nitrogen fertilization on the maturity, yield and chipping quality of potatoes 28
G. W. HOPE, D. C. MACKAY AND L. R. TOWNSEND

A study of potato harvesting at Tulelake, California 34
J. R. TAVERNETTI AND K. G. BAGHOTT

NEWS AND REVIEWS

Chemicals and foods 38
EZRA TAFT BENSON

1960 Meeting Potato Association of America 42
HENRY DARLING

Plant Pathology: The Diseased Plant (Book Review) 42
B. H. DAVIS

Total Potato Stocks January 1, 1960 42

14th National Conference on Handling Perishable Agricultural Commodities 44

International Potato Research Projects 44

Official Publication of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY, U. S. A.

American Potato Journal

PUBLISHED BY
THE POTATO ASSOCIATION OF AMERICA
NEW BRUNSWICK, N. J.

EXECUTIVE COMMITTEE

J. C. CAMPBELL, *Editor-in-Chief*
E. S. CLARK, *Associate Editor*
WM. H. MARTIN, *Honorary Editor*

Rutgers University, New Brunswick, New Jersey

PAUL J. EASTMAN, *President* .....Department of Agriculture, Augusta, Maine
ORRIN C. TURNQUIST, *President-Elect* .....University of Minnesota, St. Paul, Minn.
ROBERT V. AKELEY, *Vice President* ....U. S. Department of Agriculture, Beltsville, Md.
RICHARD L. SAWYER, *Secretary* .....Cornell University, Riverhead, N. Y.
JOHN C. CAMPBELL, *Treasurer* .....Rutgers University, New Brunswick, N. J.
W. J. HOOKER, *Past President* .....Michigan State University, East Lansing, Mich.
CHARLES E. CUNNINGHAM, *Director* .....Red Dot Foods, Inc., Madison, Wis.
D. S. MACLACHLAN, *Director* .....Department of Agriculture, Ottawa, Canada
WALTER C. SPARKS, *Director* .....Agricultural Experiment Station, Aberdeen, Idaho

Price $4.00 per year in North America; $5.00 in other countries.

Not responsible for free replacement of non-delivered or damaged issues after 90 days.

Entered as second class matter at New Brunswick, N. J., March 14, 1942 under Act of March 3, 1879. Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

SUSTAINING MEMBERS

STARKS FARMS INC. .....Route 3, Rhinelander, Wisconsin
BACON BROTHERS .....1425 So. Racine Ave., Chicago 8, Illinois
L. L. OLDS SEED CO. .....Madison, Wisconsin
FRANK L. CLARK, Founder — Clark Seed Farms .....Richford, New York
RED DOT FOODS, INC. .....Madison, Wisconsin
ROHM & HAAS COMPANY .....Philadelphia, Pennsylvania
WISE POTATO CHIP CO. .....Berwick, Pennsylvania
S. KENNEDY & SONS, Growers and Shippers of Potatoes and Onions..Clear Lake, Iowa
AMERICAN AGRICULTURAL CHEMICAL CO. .....Carteret, New Jersey
LOCKWOOD GRADER CORP. .....Gering, Nebraska
E. I. DU PONT DE NEMOURS AND CO. (INC.)
Grasselli Chemicals Dept. .....Wilmington 98, Delaware

CORRECTION OF LEAF NECROSIS OF POTATOES WITH FOLIAR AND SOIL APPLICATIONS OF POTASSIUM[1]

WINSTON M. LAUGHLIN AND CURTIS H. DEARBORN[2]

As potato growing in the Matanuska Valley has intensified since World War II, many farmers have observed leaf symptoms commonly assumed to be "early blight". No early blight fungus has ever been recovered from infested plants (2). A field showing conspicuous leaf necrosis or "early blight", as it then was called, was sampled in 1949 and plant specimens were given an intensive pathological analysis. No blight pathogens were found on either leaves or tubers .

Description of Foliar Necrosis. In severe cases the foliage of potatoes develops necrotic spots. Entire leaves and then the whole plant may turn brown and die six weeks to a month before the growing season ends.

In very early stages an affected field exhibits an over-all abnormally dark green color. This abnormally dark green color is the only symptom resembling those described in Hunger Signs in Crops (1). The first leaf symptoms are a few light green spots the size of a pin head appearing between the veins of the larger leaflets. This phase gives the appearance of a mild mosaic infestation that may have on occasion been so diagnosed (2, 3, 4).

Leaf and flower development usually stops. Leaf margins roll upward on leaves from the middle of the plant to the top (Figure 1). After several days of unfavorable conditions these small spots enlarge and combine with others. This condition resembles the symptoms reported on Netted Gem potatoes grown in California with a low level of potassium (5). When conditions favorable for this leaf breakdown continue for a week or more, practically all of the leaves on the plant are rolled, crisp, and brown (Figure 2). In milder cases bronzing of the older leaves may be the final manifestation. Flowering may occur, but seedballs are rarely set under these conditions.

History. After 1951—a period of rapidly increasing fertilizer use—potato leaf spot increased at an alarming rate in Alaska's Matanuska Valley. In certain fields all plants within localized areas died before completing their vegetative growth. In some places yields were reduced by one quarter or a half, obviously because of this malady.

In 1953 the Matanuska Valley potato industry experienced especially heavy losses caused by leaf dying. There were also reports of losses in the Tanana Valley where such terms as "fertilizer burn" and "phosphate burn" were used to describe the trouble.

In a few Matanuska Valley fields initial leaf necrosis was followed within three weeks by death of the entire plant. One grower used two rates of an 8-32-8 fertilizer on his potatoes, with the most trouble showing up at the higher rate. Losses seemed generally more severe in fields fertilized with large quantities of nitrogen and phosphorus, but little potassium. Potato rows crossing places where stump rows had been burned showed few or no symptoms. These clues suggested that lack of some minor element

[1]Accepted for publication April 10, 1959.

[2]Soil Scientist and Horticulturist, respectively, Alaska Agricultural Experiment Station, Palmer, Alaska.

FIGURE 1.—Rolling of potato leaf margins toward midrib, a symptom of acute potassium deficiency.

or potassium might cause the leaf spots, although the symptoms did not resemble potassium deficiency symptoms of potatoes described elsewhere on this continent or Europe.

MATERIALS AND METHODS

In 1954 both major and minor elements were sidedressed in a field showing severe symptoms after the vines were full grown and tubers well set. No corrective action was observed. Leaf sprays containing minor elements applied through July and August did not reduce the severity of the symptoms.

In 1955 a greenhouse study of two soils—known to have produced severe symptoms the previous year—showed that relatively heavy fertiliza-

FIGURE 2.—Practically all potato leaves become rolled, crisp and brown under conditions favorable for breakdown.

tion was not in itself the sole cause. Best plant growth was obtained from the heaviest fertilizer application.

In the same year a field experiment proved the cause could not be attributed to minor elements nor to higher fertilization levels. Under Alaskan conditions 1500 pounds per acre is nearly double the rate used by most growers. Seven minor elements were applied with two rates of N-P-K fertilizer—750 and 1500 pounds of 8-24-8 per acre. Rows were opened and the two rates of fertilizer applied in bands with a conventional potato planter. The covering discs were removed so the rows would remain

open. The minor elements were applied by hand within the opened trench. Then all fertilizer was removed from the planter, the cover discs replaced, and the seed pieces planted by running the planter through the rows a second time. Response was evaluated with a potato seedling which previously had shown the breakdown. Eight other varieties including Arctic Seedling, Green Mountain, Kennebec, and Alaska 114 were also used. No necrosis was observed up to August 17 when a frost killed the vines. In this study neither high levels of minor elements nor high fertilizer levels induced leaf necrosis.

At this time Leach (3) suggested that the leaf symptoms resembled those occasionally found in rapidly growing tobacco plants deficient in potassium. He advanced a theory accounting for the disparity between this and other more commonly accepted potash deficiency symptoms in potatoes, and relating the deficiency to what had formerly been considered a mild mosaic. His theory was at least partially confirmed by later studies.

That potash deficiency was the probable cause of these leaf symptoms was verified in 1956 when potatoes were again planted in a well-managed field south of Palmer in the Matanuska Valley, which had produced low yields the preceding year. At planting time 60, 180, and 60 pounds of N, P_2O_5, and K_2O per acre respectively were banded in the row. Supplied as a commercial fertilizer mix, all of the nitrogen was in the ammonium form. Potassium was in the chloride form.

Eight 25-foot sections of row were chosen at random in this field for foliar sprays. Beginning July 6, when the plants were four inches high, these plots were sprayed twice a week with a one per cent muriate of potash solution containing a small amount of detergent to insure leaf wetting. Throughout the growing season 18 sprays were applied to these particular plots. A total of 12 pounds K_2O per acre was sprayed on in this manner.

Results

On September 7 these sprayed plots, together with eight untreated plots were harvested. Numbers and weights of tubers and vines are recorded in table 1. Although tuber and vine yields were more than doubled by foliar sprays, there was no difference in tuber set.

In plots adjacent to the sprayed area where 44 and 132 pounds of K_2O per acre had been applied in bands by machine planting, leaf and stem tissue tests made July 3 showed adequate potassium to be present. Soil tests showed "low potassium" in plots receiving only 44 pounds of K_2O per acre but "high potassium" where 132 pounds had been applied. Soil samples were taken at the seed piece level between seed pieces in the row.

Relation to Weather. Observations throughout the season indicated the breakdown of potato foliage was partly dependent upon the weather. For example, the first breakdown was seen on the afternoon of July 12. This was the second clear day after a period of cloudy rainy weather. On July 13 the necrotic spots were general in the field except on sprayed vines. Three days later, July 16—with the sunny weather and rapid growth continuing—the spread of leaf spot over the field seemed to have stopped. Plants earlier affected seemed to have improved a little.

TABLE 1.—*Influence of muriate of potash on number and weight of tubers and foliage, Matanuska Valley, 1956.*
(Values are means of eight measurements).[1]

Treatment	Tubers per 25 ft. row	Tubers	Vines
	Number	Tons per acre	
Not sprayed	50.2	6.15	3.76
KCl sprayed	58.5	13.71	7.55
L.S.D. 5 per cent level	--	2.64	0.81
1 per cent level	--	3.91	1.20

[1]Soil test value showed 180 pounds K_2O at planting time; 60 pounds of N, 180 pounds of P_2O_5 and 60 pounds of K_2O were applied in the complete fertilizer.

By July 27 plants all over the field again showed more necrotic spots in their leaves. Again the sun had shone brightly during July 25, 26, and 27. At this time sprayed potato vines were much lighter green in color than unsprayed vines. Although some necrotic spots appeared in the leaves of sprayed vines, they were not nearly as pronounced as on vines not sprayed.

On August 9 new areas of leaf-dying were apparent. This was the second day of sunshine after rain two days before. After this date the breakdown in this field was rapid. From a distance it appeared as though the plants were killed by frost—or had been infected by early blight. In contrast, sprayed plants remained green throughout the season. Leaflets from half way down unsprayed plants contained very high nitrogen, medium phosphate, and low to no potassium in their tissues. Comparable sprayed plant tissues contained medium to high potassium.

These observations suggest that the failure of the growing potato plant to absorb and utilize soil potash is related to weather or growing cycles. The onset of foliage breakdown was commonly observed after a day or so of bright warm sunny weather, following a cool rainy period that replenishes soil moisture. This sequence suggests that soil temperatures have cooled because of additional water, while warm air temperature and abundant sunlight accelerate leaf growth. Long days encourage rapid vegetative growth. Regardless of the amount of potash present in the soil, the roots seem unable to absorb it fast enough to satisfy the plant's great need at this time. After mid-July, when the plant has attained one-half to two-thirds of its vegetative growth, this chain of events means that a rapidly growing plant is suddenly inhibited by insufficient potassium within its tissues. Under these conditions leaf breakdown is extremely rapid.

On the first sunshiny day a field may seem normal. The next day its foliage is dark green, but the change is difficult to detect and may seem illusory—a result of brilliant lighting. By the third day up to 90 per cent of all plants in a localized area show leaf spots. The fourth day of sunshine may lead to complete browning—a phenomenon that suggests early blight.

1957 Responses

A study was designed to answer questions resulting from observations and field work in 1956. A 4 x 2^2 factorial experiment was laid out, replicated eight times. There were four K_2O levels (0, 80, 160, and 320 pounds per acre), two methods of K application (row and broadcast), and "sprayed" and "not sprayed" with a one per cent solution of muriate of potash twice a week. Located on a field adjacent to one showing severe leaf breakdown in 1956, these plots were fertilized May 24 and planted with cut Arctic Seedling potatoes. All plots were fertilized with 11-48-0, applying 60 and 262 pounds of N and P_2O_5 per acre, respectively. Soil samples collected May 24 prior to fertilization showed the following ranges in soil test values using a modified Morgan's procedure with sodium acetate extractant buffered at pH 4.8: soil reaction, pH 6.1-6.3; nitrate nitrogen, 16-48; phosphate, 9-12; potash, 0-30; calcium, 2300-2800 and magnesium, 300-580 pounds per acre, respectively. With the exception of low potash, all values were similar to those of other well fertilized fields in this area.

The first leaf spray was applied June 27. Foliar necrosis was first noted July 8 after a day of bright sunshine following a period of relatively cool cloudy weather. On July 11 a count was made in each plot of all plants showing this foliage breakdown.

By mid-September plants receiving no soil K applications and no spray were dead. All plots receiving 160 pounds or more of K_2O per acre and those receiving the K spray still had green foliage when harvested September 17.

After harvest the tubers were kept three days in a warm room and then stored three weeks at approximately 40° F. They were then washed, sized, and weighed. Tubers with brown sunken lesions at the stolon end were graded from the U.S. No. 1 group.

Response to Soil Potassium

Foliage Breakdown. By July 11 each potassium increment, up to and including 160 pounds per acre, reduced by a highly significant amount the number of plants showing foliage breakdown. Application of 320 pounds of K_2O was no better than 160 pounds per acre in controlling the leaf necrosis. Furthermore, foliar breakdown occurred equally on band and broadcast fertilizer placements. Potassium foliar sprays decreased by half those plants showing foliage breakdown (Table 2).

Yield Response of Tubers to Soil Potassium. On unsprayed plots yields of U.S. No. 1 tubers went up from 3.26 to 7.92 tons per acre when 80 pounds of K_2O per acre were added (Table 3). The addition of 160 pounds raised yields another 2.46 tons per acre. No further yield increase occurred with the 320 pound treatment. On this field 160 pounds of K_2O applied in the soil seemed to be all the potato crop could utilize.

Although U.S. No. 1 yields with 160 and 320 pounds of K_2O were the same, the 160-pound level produced more small tubers. This may indicate a greater yield potential from the 160-pound treatment providing the frost period is long enough for the tubers to increase in size.

Yield Response of Tubers to Potassium Sprays. Yield differences between sprayed plots with no K supplied to the soil and 80 pound K_2O

TABLE 2.—*Effect of potassium and potassium placement, and potassium spray on foliage breakdown, Matanuska Valley, July 11, 1957.*

Treatment Lbs/acre	Plants Showing Necrosis
Effect of potassium (mean of 32 measurements)	
	Number
0 potash	10.0
80 potash	3.8
160 potash	1.1
320 potash	1.1
L.S.D. 5 per cent level	1.9
1 per cent level	2.6
Effect of fertilizer placement (mean of 64 measurements)	
Row application	4.3
Broadcast application	3.7
Effect of spray (mean of 64 measurements)	
No spray	5.6
Sprayed with potash	2.4
L.S.D. 5 per cent level	1.4
1 per cent level	1.8

TABLE 3.—*Interaction of potassium sprays and soil potassium applications, Matanuska Valley, 1957.*
(all values are means of 16 measurements)

Treatment Lbs./acre	U.S. No. 1		Tubers <2" diameter		Proportion U.S. No. 1	
	No spray	Spray	No spray	Spray	No spray	Spray
	Tons/acre		Tons/acre		Per cent	
0 potash	3.26	8.64	1.76	0.90	45.2	67.9
80 potash	7.92	11.31	0.88	0.58	68.8	79.4
160 potash	10.38	12.30	0.68	0.47	74.0	82.2
320 potash	10.37	11.61	0.41	0.38	75.7	78.9
L.S.D. 5 per cent level	1.25		0.22		6.2	
L.S.D. 1 per cent level	1.66		0.29		8.2	

per acre (Column 3, Table 3) were highly significant. Where no K was applied to the soil, K foliar spray produced 8.64 tons of U.S. No. 1 tubers, as compared with a 11.31 ton yield from plots receiving 80 pounds of

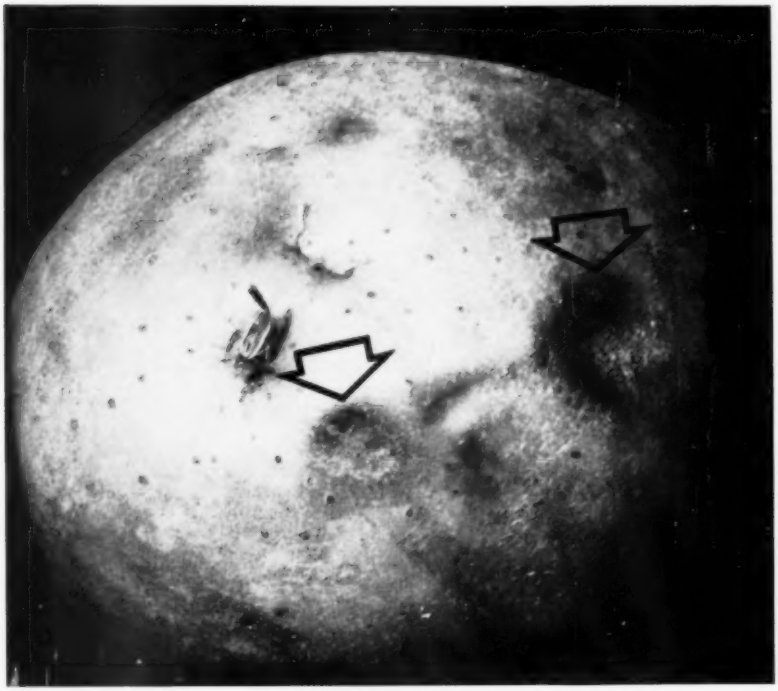

FIGURE 3.—Brown sunken lesions, shown as depressions on the surface of the stolon end of tuber.

K_2O fertilizer in the soil and also sprayed. Potassium fertilizer applications exceeding 80 pounds K_2O per acre did not increase yields when the foliage was sprayed with K .

Spraying hastened tuber development. Yields of small potatoes were materially decreased by spraying, particularly at the low soil K levels.

Potassium sprays increased yields at all levels of soil K fertilization (columns 2 and 3 of Table 3). The greater gains were at the lower K levels. Twelve pounds of K_2O applied in foliar sprays twice weekly throughout the season gave yields comparable to 80 pounds applied in the soil. Foliar sprays increased the tuber grade at all but the highest soil K level (Table 3, columns 6 and 7).

Tuber Injury Related to Leaf Dying. Tubers of potatoes inadequately supplied with potassium for top growth frequently break down, especially after bruising. This breakdown consists of numerous small depressions in the cortical layer (Figure 3). These brown sunken lesions are commonly thought to be caused by bruises incurred during harvest.

Brown sunken lesions are often found when bruising has not caused visible skin injury. Tissue beneath the skin of a slight bruise for a depth of an eighth to a fourth of an inch undergoes dehydration (Figure 4).

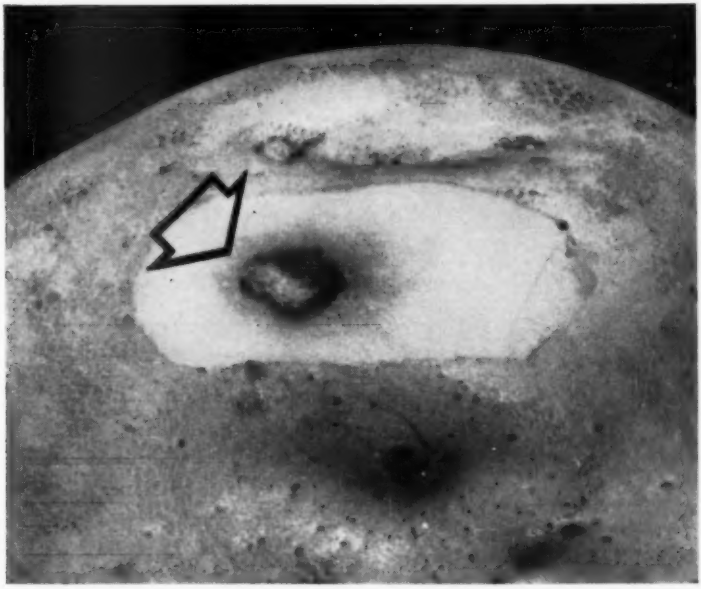

FIGURE 4.—Brown sunken lesion on potato cut to show discoloration and corky layer.

Epidermal tissue usually remains intact but follows the shrinkage of cortical tissue beneath to form a depression on the surface. As the bruised tissue contracts, it is walled off from healthy tissue by a corky layer. The area has a brownish-black appearance as viewed through the skin. It is grey in color when cut through with a knife. Frequently there is a hollow spot an eighth inch or so in diameter just under the skin. In a few varieties enough cortical tissue between the skin and the hollow spot may remain healthy to make it difficult to detect damage deeper in the tuber. In other varieties this corky cup can be separated and removed from the healthy tissue as a deep scab pit can be popped out of a tuber with the finger nail.

Practically all visible shrinkage associated with brown sunken lesions takes place within 12 to 18 days after harvest. After this time little or no change occurs. Tuber decay does not take place in these depressions even when the tubers are held in common storage for 8 to 11 months.

This condition had been recognized in previous years as a weakness of certain varieties, especially when growing conditions favor a high dry matter content.

Lesions were most common on tubers grown in soil low in potassium. Losses varied over the range of soil K studied. Table 4 shows how the smallest grade-out losses from lesions were associated with the highest soil K level. Percentage-wise each K increment decreased losses.

Spraying potato tops with K where no K had been added to the soil gave the most tuber lesions. Although grade-out losses on sprayed plots

TABLE 4.—*Weight and proportion of tubers showing brown sunken lesions, Matanuska Valley, 1957.*
(all values are means of 16 measurements)

Lbs./acre	Tons per acre		Percentage	
	No spray	Spray	No spray	Spray
0 potash	1.15	2.13	33.0	26.9
80 potash	1.80	0.86	23.4	8.6
160 potash	1.04	0.64	11.1	5.4
320 potash	0.71	0.36	6.7	3.3
L.S.D. 5 per cent level	0.63		8.7	
1 per cent level	0.84		11.6	

TABLE 5.—*Interaction of soil and spray potash, Matanuska Valley, 1957.*
(all values are means of 16 measurements).

Lbs./acre	Per cent Dry Matter	
	No Spray	Spray
0 potash	22.81	24.01
80 potash	23.52	23.11
160 potash	23.32	22.36
320 potash	22.25	21.53
L.S.D. 5 per cent level	0.42	
1 per cent level	0.54	

receiving no soil K was nearly twice that of unsprayed (Table 4), the percentage of tubers affected was about the same. This points up increased yields obtained by spraying. Where some K was available in the soil, foliar K sprays markedly reduced losses caused by lesions.

Table 5 shows the relationship of K applied to the soil and dry matter accumulated in the tubers. When soil K was so low that early plant growth was severely curtailed, less dry matter was stored. For example, the dry matter content of tubers grown in soil receiving 0 and 80 pounds of K_2O was 22.81 and 23.52 per cent, respectively. Progressively less dry matter was stored where the 160 and 320 levels of K were used. Although potatoes receiving K only in foliar sprays had the highest dry matter content, this advantage was offset by low yields and large grade out losses from lesions.

The relationship of brown sunken lesions, high dry matter and low yields is brought out by comparing dry matter content (Table 5), grade-out due to tuber lesions (Table 4), and yields of U.S. No. 1 tubers (Table 3) with K levels. Other investigators have found that high K levels result in less dry matter being stored when other conditions are favorable for growth. K sprays favored dry matter accumulation when the K-supplying capacity of the soil was low .

Discussion

These studies show that spotted leaf necrosis and tuber lesions, common in Alaska's Matanuska Valley potato industry, are caused by potassium deficiency. Even when 160 pounds of potash were supplied in conventional soil applications, potatoes responded to additional potash sprayed on their foliage. Spraying gave significant gains in yields and reduced grade-out losses due to tuber lesions. Foliar potash sprays at the 160-pound soil potash level reduced the dry matter content of tubers although the reduction probably was not of sufficient magnitude to detract from quality.

In the light of these studies together with a failure to identify *Alternaria solani* in Alaska it is concluded that early references to "early blight" probably reflect potash deficiency.

Bruising leads to the development of brown sunken lesions in tubers from plants which have undergone K deficiency sometime during the growing season. Lesions are most common on the stolon-end shoulders. Reports from British Columbia and Holland (6) describe a similar breakdown as "blue spotting".

Varieties differ in their response to soil potash levels. Alaska 114 has not shown leaf spot when grown on soils where the foliage of Green Mountain has been affected. However, Alaska 114 has developed brown sunken lesions much deeper in the tuber than Green Mountain.

The economic feasibility of utilizing foliar potash sprays in Alaska's potato industry is not yet determined. As a compromise measure it is now recommended that potatoes planted in fields that have previously exhibited deficiency symptoms be sprayed once a week with a 1 per cent potassium sulfate solution, until the vines are large enough to be mechanically damaged by further traffic. Too much travel over the field after hilling crushes the vines and exposes tubers to greening.

Summary

Foliage breakdown was markedly reduced by soil and spray applications of muriate of potash and not influenced by placement of the K fertilizer.

U.S. No. 1 tuber yields in the absence of K sprays were increased by each increment of soil K through 160 pounds K_2O per acre. The weight of tubers below two inches in diameter in the absence of K sprays was reduced with each increment of soil K.

Muriate of potash sprays twice weekly increased the yield and proportion of U.S. No. 1 tubers at all soil K levels. The greatest gain was with the lower K levels. No additional yields on sprayed plots occurred above 160 pounds K_2O per acre. Yield of small tubers was reduced markedly by spraying at the lower K levels.

The highest incidence of brown sunken lesions occurred where no K had been added to the soil and the foliar sprayed. Where some K was available, foliar K sprays significantly reduced this cortical breakdown.

Dry matter content of tubers was not materially reduced by soil K applications up to and including 160 pounds per acre. Where soil potash was applied, foliar potash sprays reduced tuber dry matter content.

Literature Cited

1. Bear, Firman E., *et al.* 1949. Hunger signs in crops. The Am. Soc. of Agron. and the Nat. Fert. Assoc.
2. Gasser, G. W., and C. L. Lefebre. 1949. Growing potatoes in Alaska. Alaska Dept. of Agr., Circ. 6.
3. Leach, J. G. 1955. Diseases and insect pests of potatoes in Alaska. A report of a two months' study, July 15 to September 15, 1955. Alaska Agr. Exp. Sta. Mimeo Report.
4. Leach, J. G. 1955. Notes on potato leaf bronzing. Communication with Director Don L. Irwin, Alaska Agr. Exp. Sta.
5. Lorenz, O. A., F. A. Takatori, Marvin Snyder, Harwood Hall ,and Herman Timm. 1958. Potato fertilization and internal black spot in the Santa Maria Valley. Calif. Agr. 12: 8, 9, 10.
6. Wright, N. S. 1957. Blue spotting of potato tubers in British Columbia. Plant Disease Reptr. 41: 608-611.

POTATO SPINDLE TUBER IN EASTERN CANADA[1]

D. S. MacLachlan[2]

Introduction

The potato spindle tuber disease was first reported on the North American Continent in New Jersey in 1922 by W. H. Martin (6). Martin described the symptoms of the disease in Irish Cobbler potatoes, and suggested that it had reached New Jersey in seed potatoes from Maine. Folsom (3) observed spindle tuber in Maine in 1924, and in 1930, Martin visited Prince Edward Island and found spindle tuber in potato crops growing there. Although the disease persisted in Eastern Canada, it was not until 1950 that it reached serious proportions. In that year, 57 fields were rejected for certification on Prince Edward Island alone because of excess of spindle tuber. It is interesting to note that this sudden rise in the incidence of the disease coincided with the planting of large acreages of Sebago potatoes.

Spindle tuber has been reported to be spread in the fields by aphids, flea-beetles, grasshoppers, Colorado potato beetles and tarnished plant bugs (4). Transmission has also been obtained with potato cutting knives, cultivators, sprayers, planters, and by contact of healthy with diseased sets and foliage (5). In spite of the apparent ease with which the disease is disseminated, Bonde (2) in 1938, stated that in Maine in normal years the spread of spindle tuber was negligible.

Attempts to prepare an antiserum for spindle tuber have been unsuccessful (7), and there are no reports of transfer of the disease to hosts other than the potato. Identification of the disease is dependent on the recognition of variable foliage symptoms in potato and on the spindling of the tubers.

This investigation was initiated to determine if spindle tuber, as it occurs in Eastern Canada, is of virus origin, and to find suitable local lesion or systemic hosts for its identification.

Materials and Methods

In 1954, tubers were collected from potato plants showing spindle tuber at forty-six locations in Eastern Canada. Tubers of U.S.D.A. Seedling 41956 infected with spindle tuber were supplied by Dr. R. E. Webb, Plant Industry Station, Beltsville, Md. In 1955, plants were grown from the infected tubers in the greenhouse, and scions from plants of each of the 47 collections were grafted to U.S.D.A. Seedling 41956 to remove potato virus X. Seventeen of the 47 collections were selected as stock materials. These plants were then checked serologically, and by inoculating indicator hosts to ensure that they were free of potato viruses X, Y, A, and leafroll. The varieties from which the isolates were taken, and the place of collection are recorded in table 1.

[1]Accepted for publication May 18, 1959.
Contribution No. 6 from the Plant Research Institute, Research Branch, Canada Department of Agriculture, Central Experimental Farm, Ottawa.
[2]Plant Pathologist, Plant Research Institute, Research Branch, Central Experimental Farm, Ottawa, Canada.

TABLE 1.—*Source and variety of potato tubers used as stock cultures of spindle tuber virus.*

Code	Variety	Location	Date
S.T. 1	Seedling 41956	Presque Isle, Me.	1954
S.T. 2	Green Mountain	Smithfield, Ont.	1953
S.T. 3	Kennebec	" "	1953
S.T. 4	Netted Gem	Ste. Clothilde, Que.	1954
S.T. 5	Sebago	" " "	1954
S.T. 6	Kennebec	" " "	1954
S.T. 7	Cherokee	L'Assomption, Que.	1954
S.T. 8	Canus	" "	1954
S.T. 9	Katahdin	Ste. Anne de la Pocatiere, Que.	1954
S.T. 10	Katahdin	Cabano, Que.	1954
S.T. 11	Kennebec	Barrie, Ont.	1953
S.T. 12	Irish Cobbler	Shawville, Que.	1953
S.T. 13	Sebago	Grand Falls, N. B.	1953
S.T. 14	Kennebec	" " "	1954
S.T. 15	Kennebec	Summerside, P. E. I.	1954
S.T. 16	Sebago	Charlottetown, P. E. I.	1954
S.T. 17	Sebago	Kensington, P. E. I.	1954

The mechanical inoculations were made with sap from the stock cultures in Seedling 41956 diluted 1:5 with 0.1M phosphate buffer (pH 7.0). Carborundum was used as an abrasive.

In the insect transmission tests the potato aphid *Macrosyphum solanifolii* Ashm. and the green peach aphid *Myzus persicae* Sulz. were used. Non-viruliferous aphids were reared on healthy potato plants (Seedling 41956), transferred to plants of Seedling 41956 that showed symptoms of spindle tuber, and allowed to feed for 48 hours. The aphids were than transferred to the host to be tested and allowed to feed for 7 days.

EXPERIMENTAL RESULTS

Symptoms in the Greenhouse

When plants of Seedling 41956 were grafted with scions from plants that were showing spindle tuber symptoms, the grafted plants failed to develop symptoms during the current season. Tubers harvested from these plants were not spindled. When the daughter tubers were planted, the resulting plants showed two distinct types of symptoms. The most common symptom resembled the symptoms of purple top or bunch top, the disease attributed to aster yellows infection, but the upward rolling of the terminal leaves, and the accumulation of pigment was not as severe as that caused by typical purple top.

The second symptom type observed was a severe spindling and stunting of the plants. There was a marked proliferation of the axillary buds, and the symptoms somewhat resembled those of plants infected with witches' broom virus. Six of the original seventeen isolates showed this type of symptom.

Some of the tubers from both symptom types were spindled, but the reaction was variable.

Mechanical Transmission

Inoculum for the mechanical transmission experiments was taken from potato plants (Seedling 41956) showing the purple top and witches' broom type of symptom. A total of 188 plant species in the genera *Apium, Chenopodium, Cucumis, Datura, Gomphrena, Hyocyamus, Indigofera, Lycium, Lycopersicon, Melilotus, Nicandra, Petunia, Pisum, Phaseolus, Physalis, Saracha, Solanum,* and *Trifolium* were inoculated. Ten plants of each of the above species were inoculated with sap from potato plants exhibiting each of the two symptom types. Following inoculation, five of the plants were placed in a greenhouse held at 18°C., and five at 24°C. The plants were examined periodically for the appearance of symptoms up to a maximum of 30 days.

Local lesions or systemic symptoms were not observed on any of the inoculated species, and no attempt was made to determine if the virus may have been carried without symptom expression in any of the inoculated plants.

An attempt was also made to transmit the spindle tuber virus, by rubbing, to the potato varieties Kennebec, Green Mountain, Irish Cobbler, Sebago, and Huron in the greenhouse. The plants were grown from single eyes taken from indexed stock, and the inoculations were made when the plants were approximately 3 inches in height. No foliage symptoms were observed during the growing season, and the tubers did not show signs of spindling at harvesting. The harvested tubers were stored and planted in the field the following spring. No symptoms were observed on the plants in the field, and the tubers were again of normal shape.

The cut surfaces of 50 healthy sets of both Kennebec and Sebago potatoes were rubbed against the freshly cut surface of spindled Kennebec tubers. Following inoculation, both the inoculated and naturally infected sets were planted in the field. The plots were sprayed weekly with both fungicide and insecticide, and there was no indication of an infestation of aphids, flea-beetles or leafhoppers.

Two of the 20 plants arising from naturally infected sets showed an upright type of growth throughout the season, but none of the 50 plants of Kennebec or 50 plants of Sebago showed any symptoms characteristic of spindle tuber.

The tubers harvested from both plots showed no abnormalities. In fact, there was more evidence of spindling in tubers grown from healthy indexed Kennebec tubers than in tubers from either the naturally infected or inoculated Kennebec or Sebago sets.

Aphid Transmission

A second series of host plants of the same species which were inoculated mechanically was colonized with viruliferous potato, and green peach aphids. Ten aphids were placed on each plant, and they were allowed to feed for 7 days. The plants were held at 18°C. for a maximum of 30 days.

As in the mechanical transmission attempts, no symptoms, either local or systemic, were observed on the test plants. In many instances the aphids did not remain viable for the seven-day feeding period, and, in fact, may not have fed on the test plants.

Dodder Transmission

Healthy dodder, *Cuscuta gronovii* Willd., was trained from potato (Seedling 41956) infected with spindle tuber to *Lycopersicon esculentum* var. Stokesdale, *Nicotiana tabacum* L. var. Havana 38, and *Nicotiana glutinosa* L. The dodder was left attached to the host plant for approximately one month. Plants of Stokesdale tomato began to show abnormal growth about 40 days after being colonized with dodder. Only plants attached to the 41956 seedlings showing the purple top type of symptom showed symptoms. The symptoms in tomato consisted of a marked stunting, a proliferation of the axillary buds, necrosis of the flower buds, and a reduction in size and a rugosity of the leaves. The symptoms were suggestive of those caused by the big bud virus on tomatoes in Australia (8).

Dodder transmission of virus from infected tomato to aster and to *Vinca rosea* was attempted. No symptoms were observed in aster, but the *Vinca* plants became chlorotic, stunted and produced flowers showing extreme phyllody. Transmissions by dodder from tomato and Vinca to potato Seedling 41956 produced mild purple top symptoms. Some of the tubers harvested from these plants were spindled, but, as in the case of the original isolates, the tuber reaction was variable.

Graft Transmission

Scions from plants of Seedling 41956 which showed both types of symptoms described previously, were grafted to tomato and *Vinca rosea*. The scions grew well on tomato, but failed to survive on *Vinca*. Six weeks after grafting, the tomato plants which had been grafted with scions from Seedling 41956 showing the purple-top type of symptoms were definitely stunted. The leaves were smaller and rugose, and the axillary buds had begun to produce shoots. No symptoms were observed on tomato plants grafted with scions from the witches' broom type of potato plant.

Antiserum Production

Crude sap from potato, tomato, and *Vinca rosea* infected with spindle tuber virus was partially clarified by centrifuging at 10,000 r.p.m. for 10 minutes. The preparations were then injected intervenously into rabbits at 4-day intervals. Tests for antiserum production at the end of the 4th, 8th and 12th injection were negative.

Discussion and Conclusions

The literature on potato spindle tuber virus stresses the ease with which the virus is transmitted from potato to potato in the field through leaf contact, by a variety of insect vectors, or by cultivating and spraying equipment. The virus is also reported to be spread by the potato cutting knife, and by contact between the cut surfaces of healthy and diseased tubers. These reports indicate that the spindle tuber virus is at least as infectious as potato virus X when transmitted mechanically, and in addition spindle tuber is transmitted by insects, which is not the case with potato virus X. We now know that there are very few seed sources of the older established potato varieties which are not totally infected with virus X, and that elaborate precautions must be employed to maintain stocks free from virus X. In the light of these observations, it is difficult

to believe that any of the seed sources of our popular potato varieties are not totally infected with the spindle tuber virus, unless some of these varieties are resistant to infection. Unfortunately, the only criteria that may be used in identifying the disease are variable symptoms on potato foliage, and the spindling of the tubers. Because of this, a high proportion of field-infections could remain undetected.

In the experiments reported in this paper, no symptoms which could be interpreted as being due to spindle-tuber virus infection were observed on the foliage of Kennebec, Sebago, Irish Cobbler or Green Mountain potatoes in the greenhouse. The tubers harvested from plants arising from spindled tubers were usually of normal shape. If we are to agree with present reports in the literature, we must assume that, as the plants were grown from tubers showing spindle tuber in the field, the virus is present and that the normal symptoms of infection were masked by greenhouse conditions.

When plants from spindled tubers were grafted to Seedling 41956, two distinct types of symptoms were produced. Neither of these symptom types resembled those caused by spindle tuber infection in the field. These symptoms appeared in over 90 per cent of the plants of Seedling 41956 grafted with scions from potato plants showing spindle tuber symptoms in the field. Graft and dodder transmission experiments have indicated that one of these symptom types is due to virus infection. It is also indicated that this virus belongs to the yellow group.

In interpreting these results, we must conclude that a virus of the yellows type is closely associated with the condition we recognize as potato spindle tuber in Eastern Canada.

Literature Cited

1. Bonde, R. 1927. The spread of spindle tuber by the knife. Amer. Potato Jour. 4: 51-52.
2. ————. 1937. Spread of virus diseases in 1937 in Aroostook County, Maine Agr. Exp. Sta. Bull. 391: 297-304.
3. Folsom, D. 1925. Virus diseases of the potato. Que. Soc. Prot. Plants, 18th Ann. Rept., pp. 14-28.
4. Goss, R. W. 1931. Infection experiments with spindle tuber and unmottled curly dwarf of the potato. Nebr. Agr. Exp. Sta. Res. Bull. 53.
5. Grotz, L. O. 1931. Transmission of spindle tuber of potatoes through the usual commercial practices. Amer. Potato Jour. 17: 73-82.
6. Martin, W. H. 1922. Spindle tuber, a new potato trouble. Hints to Potato Growers, N. J. State Potato Assoc. 3 (8).
7. Mushin, Rose. 1942. Serological studies on plant viruses. Austr. J. Exp. Biol. Med. Sci. 20: 59-63.
8. Samuel, G., J. G. Bald and C. M. Eardley. 1933. Big bud, a virus disease of the tomato. Phytopath. 23: 641-653.

POTATO SCAB CONTROL ON ORGANIC SOILS. I. INITIAL RESPONSE TO PCNB[1]

H. T. ERICKSON[2]

INTRODUCTION

Common potato scab, caused by *Streptomyces scabies*, is a disease of major economic importance, especially on muck soils of the midwest. Unlike infections in most mineral soils, severe scab on muck often occurs at soil reactions as low as pH 5.1 or 5.2 and sometimes lower. Control through lowering the soil pH, therefore, is usually impractical. Some control has been effected by early planting (5). Control of this type is associated with higher soil moisture at time of tuberization, which appears to be a critical factor in reducing inroads of scab. .

PCNB (pentachloronitrobenzene)[3] has been reported to reduce scab on organic (1) and on mineral soils (2). Application studies have indicated that broadcasting followed by a thorough mixing with disc or roto-tiller gives best results (4).

Twenty-five to 150 pounds of PCNB has controlled scab on mineral soils, with some phytotoxicity at higher rates. Residual scab control on mineral soil for one year after treatment has been reported (3). It was much less effective than the original application..

MATERIALS AND METHODS

Twenty per cent PCNB dust was used throughout these experiments. An area on the Purdue Muck Crops Farm, pH 5.3, known to have a high incidence of scab was selected. The soil contained 85 per cent organic matter in a highly oxidized, finely divided state, with a base exchange capacity of 235 m.e. per 100 gr.

In 1956, four treatments, 0, 100, 200, and 300 pounds active ingredient were applied in a randomized block design with treatments replicated four times. The material was broadcast and disced in to a depth of six to eight inches, being thoroughly incorporated with the soil. Katahdin potatoes, used throughout, were planted the following day, May 30. This date, about three weeks later than normal for the area, was selected in the hope of securing maximum scab infection. On October 16, paired rows, each 25 feet long, were harvested, the tubers weighed and 50-tuber samples were examined for scab. The standard "area" and "type" scab classification was used. An area of 1 indicates scab lesions affecting not more than 20 per cent of the surface area; 2, 3, 4, and 5 have upper limits of 40, 60, 80 and 100 per cent surface coverage respectively. Type one is an innocuous surface scab; 2, 3, 4, and 5 increase in severity from a slightly more prominent surface scab, though superficial, through rough pustules to

[1]Accepted for publication June 1, 1959.
Purdue University Agricultural Experiment Station Journal Paper No. 1294.

[2]Assistant Professor of Horticulture, Purdue University, Lafayette, Indiana.

[3]Twenty per cent PCNB dust (Terrachlor) furnished by the Olin Mathieson Company.

pitted and deeply pitted lesions respectively. A "Scab Index" was calculated as:

$$\text{Scab index} = \frac{\text{average (area x type) x per cent scabby tubers x 4}}{100}$$

The highest value possible for the index as calculated is 100; however, an index of 50 could represent nearly 100 per cent culls. All scab readings were made by the same person. Although other scab indices have been devised (6) the one employed here utilizes a scoring method that has been used at this station for several years.

In 1957, one half of each plot was given an application of PCNB similar to that applied the previous year, while the other half was not treated in 1957 and served as a residual check. Half of each 1956 "control" plot was treated in 1957 with a 200 pound application of PCNB, the other half being maintained as a control both years. The potatoes were planted on May 19 and harvested October 15. Data on scab were taken as before.

Results

Yield: Yield differences were non-significant in both years. (Table 1). Tuber size and specific gravity were similarly unaffected.

Scab Incidence: Severity of scab lesions and the number of scabby tubers were reduced by PCNB. Table 2 gives results for the initial application.

Table 1.—*Total yield and per cent "B" size tubers for seven PCNB treatments and control. 1956 and 1957. Katahdin variety.*

Pounds Actual PCNB Per Acre		Total Yield Per Acre		Yield of "B" Size Tubers	
1956	1957	1956	1957	1956	1957
		Bus.	Bus.	Per cent	Per cent
200	200		626		7.8
200	0	553	614	4.5	7.0
0	200		611		5.4
0	0	528	603	4.7	6.9
300	300		602		8.6
300	0	579	575	4.8	8.1
100	0	572	567	5.4	7.6
100	100		526		8.9
		N.S.	N.S.	N.S.	N.S.

Table 2.—*Incidence of scab-free tubers. PCNB treated plots and control. Katahdin variety. 1956.*

Pounds of PCNB Per Acre	Scab-free Tubers (Per cent)
0	9
100	34
200	49
300	55
LSD .05	17

Scab was less prevalent in 1957, perhaps due in part to the earlier planting date. Nevertheless, a definite treatment response is shown in table 3. Substantial residual control is evident at higher rates, intensified by the 1957 application, giving a cumulative response.

Percentage of scab-free tubers, although a meaningful statistic in itself, does not thoroughly describe the beneficial effects of PCNB Milder scab lesions appeared on tubers grown in treated soils, as is shown in table 4. These differences were much less pronounced in 1957, when scab was generally milder.

Inherent absorptive capacities of muck soils probably account for the high PCNB rates required. At 300 pounds per acre, excellent scab control was obtained the first year and plots receiving 600 pounds over a two year span also showed excellent control with the least scab.

In accordance with findings elsewhere (4) and unpublished results at this station, broadcast applications thoroughly incorporated with the soil were most effective. Apparently the chemical exhibits very slight mobility within the soil.

Residual activity at 200 and 300 pounds proved considerable. A direct comparison, at the 200 pound rate, of residual and current season applications revealed very slight, non-significant differences in scab incidence. (Table 3). Whether this residual effect is evidence of prolonged activity within the soil or is, instead, a manifestation of reduced inoculum level from the treatment applied the previous season is a matter of some interest. A report of phytotoxicity the year following treatment with PCNB (3) lends support to the former hypothesis.

Despite appreciable residual control at the higher PCNB levels significant improvement in scab control through current season application was apparent in every instance. Moderate yearly doses are indicated as superior to an initial massive one for best control over a period of years. Economic aspects, however, affect the practicability of general commercial usage, a matter beyond the scope of this study.

Percentage of "B" size tubers and total yield remained unaffected at the rates used. There was no evidence of toxicity, such as delayed emergence, as has been reported elsewhere (3). Howeevr, some phytotoxicity was indicated by reduced weed populations in the treated areas. No quantitative data on this effect were taken. On mineral soils of low exchange capacity, definite yield reduction has occurred at rates in excess of 150 pounds per acre. For mucks with high base exchange capacities, the safe toxic level for mineral soils should be multiplied by a factor of at least three to compensate for the added absorption capacity, assuming data from other chemically related soil amendments can be extrapolated to include PCNB. This would account for the absence of yield depression at the high rates used on muck.

Yearly differences in scab incidence were apparent as the "control" indicate. The later planting date in 1956 may have contributed to more extensive scab that year.

Tubers from plots treated with high PCNB rates were uniformly attractive. Tubers free of Rhizoctonia (black scurf) appeared in most PCNB treatments. Control of this important disease is an added possibility of PCNB (1).

TABLE 3.—*Incidence of scab-free tubers. PCNB treated plots and control. 1957.*

Rate Pounds Actual PCNB Per Acre	Per cent Scab-free Tubers	
	PCNB Applied	
	1956 only	1956 & 1957
0	28.5	58.5*
100	44.0	71.0
200	50.5	71.0
300	60.5	85.0
LSD .05 within rates	16.1	
LSD .01 within rates	22.6	
LSD .05 all other comparisons	21.5	
LSD .01 all other comparisons	30.6	

*200 pounds in 1957.

TABLE 4.—*Scab index and average classification among infected tubers for given treatments. Katahdin variety. 1956 and 1957.*

1956

Pounds Actual PCNB Per Acre	Scab		
	Area	Type	Index
0	4	3	37.0
100	3	2	12.5
200	3	2	11.0
300	3	1	7.3
	LSD .05		12.7
	LSD .01		18.6

1957

Pounds Actual PCNB Per Acre		Area	Type	Index
1956	1957			
0	0	2	3	20.8
0	200	2	3	10.0
100	0	3	3	16.5
100	100	2	2	5.0
200	0	1	4	9.0
200	200	1	3	3.5
300	0	2	2	4.0
300	300	2	2	2.0
		LSD .05		4.8
		LSD .01		6.5

Summary

Incidence of potato scab was significantly reduced on a muck soil of high exchange capacity by PCNB with no reduction in tuber yield at rates up to 300 pounds per acre. Rates of 100, 200, and 300 pounds actual fungicide were used. Broadcast application followed by thorough mixing with the soil to a 6-8 inch depth proved satisfactory. Row application was not used in these tests.

At the higher rates residual activity was apparent the year following application. Repeated treatments the second year caused further significant scab decline. Accumulative reduction in scab incidence from a series of moderate yearly doses appears to be the most efficient use of PCNB on muck soil. This practice would be inconsistent with standard cropping methods used on muck, however, since potatoes are not ordinarily raised on the same muck soil in successive seasons. Economic considerations will be important in determining the exten of PCNB use and its acceptability among potato growers.

Literature Cited

1. Hooker, W. J. 1954. Pentacloronitrobenzene soil treatment for potato scab and Rhizoctonia control. Pl. Dis. Reptr. 38: 187-192.
2. Houghland, G. V. C. and Lillian C. Cash. 1954. Effectiveness of certain soil fungicides in the control of potato scab. Pl. Dis. Reptr. 38: 777-780.
3. ———— and ————. 1957. Carry-over effects of PCNB applied to soil for control of potato scab. Amer. Potato Jour. 34: 85-88.
4. Menzies, J. D. 1957. Dosage rates and application methods with PCNB for control of potato scab and rhizoctonia. Amer. Potato Jour. 34: 219-226.
5. Samson, R. W. and N. K. Ellis. 1943. Influence of time of planting of potatoes in muck soil on yield and scab development. Amer. Potato Jour., 20: 301-308.
6. Walker, J. C., R. H. Larson and A. R. Albert. 1937. Studies of resistance of potato scab in Wisconsin. Amer. Potato Jour. 15: 246-252.

THE EFFECT OF TIME OF PLANTING ON OCCURRENCE OF INTERNAL BROWN SPOT IN THE POTATO VARIETY ARRAN BANNER IN LEBANON[1]

A. A. AHMADI, H. MOBARAK, AND JOHN OSGUTHORPE[2]

Internal brown spot of potato (known locally as chocolate spot) is a serious problem in Lebanon. The affected tubers show isolated, brownish areas in the cortex and pith. These lesions vary from few to many depending on the intensity of the malady, the nature of which is apparently not pathological but probably physiological. (3,4) No external symptoms of the disease have been observed. The cause of internal brown spot has been attributed either to phosphorus deficiency or to high temperature and low moisture content of the soil during the period of tuber maturation. (1,2,4) Preliminary investigations at the American University indicated that different levels of phosphorus and potassium applied to the soil had no significant effect on the occurrence of internal brown spot.[3]

In Lebanon potatoes are grown on clay or clay loam soils with pH ranging from 7.0 to 8.5. The potato varieties Arran Banner and Up-To-Date have been the principal varieties grown for the past two decades. The latter variety is resistant to internal brown spot but produces elongated tubers and matures late hence, it is not so popular as the former variety which unfortunately is seriously affected by the brown spot malady.

In 1957 and 1958 experiments were conducted at the experimental farm of the American University of Beirut in the Bekaa Plain and at the Lebanese Agronomic Research Institute at Terbol with the objective of determining the effect of time of planting and time of harvest on the occurrence of internal brown spot in the potato variety Arran Banner.

MATERIALS AND METHODS

1957 Experiment: Seed potatoes of the variety Arran Banner imported from Ireland were used in the experiments. The soil at the American University Experimental Farm was a clay type with pH of 8.0, while at the Lebanese Agronomic Research Station the soil was clay loam with a pH of 7.5. Each experiment was conducted as a randomized block with 3 replications and plantings at monthly intervals. The plot size was four rows each 10 x 0.6 meters. Complete commercial fertilizer was broadcast and disced into the soil at the rate of one ton of 8-8-4 per hectare.[4] Furrows were opened by tractor and potato seed pieces at space intervals of 30 cm were planted in the furrows by hand. Later the seed pieces were covered by a plow attached to a tractor. The plots were irrigated every

[1] Accepted for publication June 2, 1959.
Publication No. 8, Faculty of Agricultural Sciences, American University of Beirut, Lebanon, 1959.

[2] A. A. Ahmadi, Assistant Professor of Vegetable Crops, American University of Beirut, H. Mobarak, Lebanese Agronomic Research Institute and John Osguthorpe, Agronomist, United States Operations Mission to Lebanon, respectively.

[3] Unpublished data obtained independently by Dr. F. O. Smith and the senior author.

[4] Hectare = 2.47 acres.

TABLE 1.—*Effect of time of planting on yields and percentages of tubers with internal brown spot in 1957.*

American University Experimental Farm				Lebanese Agronomic Research Institute			
Date Planted	Date Harvested	Internal Brown Spot Per cent	Yield Tons per Hectare	Date Planted	Date Harvested	Internal Brown Spot Per cent	Yield Tons per Hectare
Mar. 29	Aug. 21	40	29.4	Mar. 8	July 7	55	26.2
June 1	Nov. 12	2	15.0	Apr. 29	Sept. 7	40	19.6
				June 3	Oct. 28	5	18.8

TABLE 2.—*Effect of time of planting on yields and percentage of tubers with internal brown spot in 1958.*

American University Experimental Farm				Lebanese Agronomic Research Institute			
Date Planted	Date Harvested	Internal Brown Spot Per cent	Yield Tons per Hectare	Date Planted	Date Harvested	Internal Brown Spot Per cent	Yield Tons per Hectare
Mar. 8	July 29	43	18.3	Feb. 2	Aug. 8	78	23.9
Apr. 9	Aug. 13	30	16.0	Feb. 28	Aug. 13	64	27.2
May 15	Sept. 2	25	11.0	Mar. 15	Aug. 26	76	28.4
June 11	Oct. 9	1	10.0	Mar. 31	Sept. 13	62	20.3
				Apr. 15	Sept. 25	37	18.4
				Apr. 30	Oct. 10	13	21.7
				May 15	Oct. 25	16	15.8
				May 31	Nov. 5	38	9.6
				June 15	Nov. 10	27	13.1
				June 31	Nov. 15	15	10.0

ten days during the growing season. The different dates of planting and harvesting are given in table 1. After each harvest one hundred tubers were picked at random from each replication and examined for internal brown spot. Also tuber samples each of 25 kg were stored at a temperature of 15-20°C. for a period of four months.

1958 Experiment: During 1958 the procedure of the experiment at the American University Farm was the same as in 1957 but at the Lebanese Agronomic Research Institute the potatoes were planted at 15-day intervals and ten different planting dates. The plot size was five rows each 5.10 x 0.70 meters. Complete commercial fertilizer was applied at the rate of one ton of 7.5-7.5-15 per hectare. The different dates of planting and harvesting are given in table 2.

FIGURE 1.—Potato tuber showing internal brown spot.

RESULTS

1957 Experiment: As shown in table 1, the occurrence of brown spot (Fig. 1) decreased with the later time of planting. This decrease was especially noticeable among tubers from plantings made during the month of June. The percentage of brown spot in tubers from the March planting was 40 at the American University Farm and 55 at the Lebanese Agronomic Research Institute, whereas those from the June planting showed 2 and 5 per cent internal brown spot, respectively. As shown in figure 2, the highest monthly temperature generally occurs during the month of August and potatoes which are mature enough for harvest at that period show a high incidence of internal brown spot. In the early plantings, potato tuber development occurs during warm periods, while those planted at later dates develop their tubers during cooler periods and consequently have a lower incidence of the disease.

These results confirm the work of Ellison and Jacob (1) who found that when potatoes were planted during the months of April and May the resultant crop contained a significantly higher percentage of internal brown spot than when planted at later dates. It should be mentioned that although potatoes planted at later dates in our experiments gave considerably lower yields than the earlier plantings the harvested tubers were superior in quality, shape and size. Moreover, most of the potatoes harvested from plantings made before June did not store well and the warm summer temperatures broke the rest period. The tubers harvested from June plantings kept firm and were free of sprouts for four months. Economically speaking, these results are important in that the superior tuber quality and higher price obtained by the growers during the winter season compensate for the lower yields.

1958 Experiment: The 1958 results are reported in table 2. The early plantings produced tubers with a considerably higher percentage of internal brown spot than later plantings. Potatoes planted during the months of April, May and June produced tubers with less than 38 per cent internal brown spot, while those planted during the months of February and March produced tubers with 43-78 per cent internal brown spot.

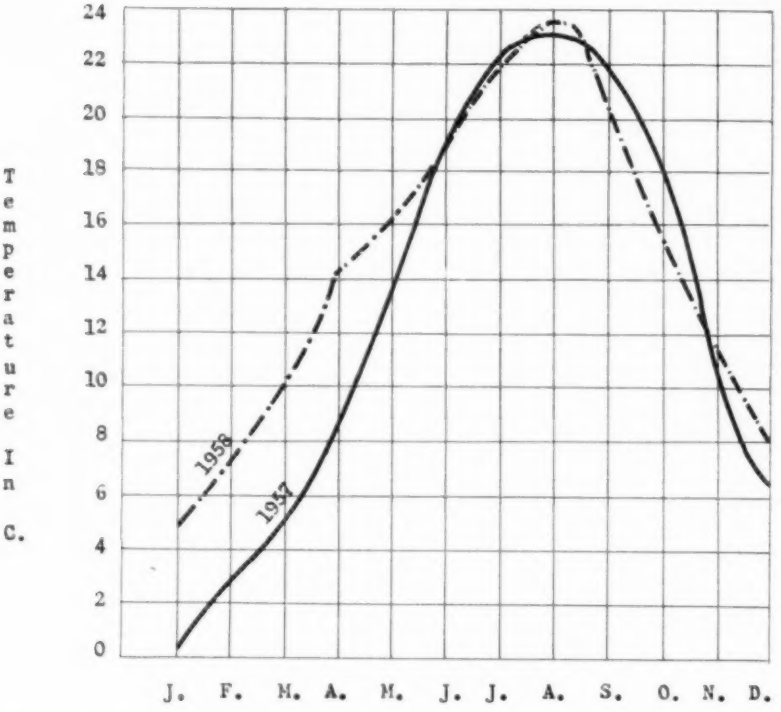

FIGURE 2.—Two year's average monthly temperatures, American University Experimental Farm, Bekaa, 1957-1958.

The data for the two years are reasonably consistent and indicate a definite relation between the time of planting and the occurrence of internal brown spot.

SUMMARY

During 1957 and 1958, experiments were conducted at American University Experimental Farm and the Lebanese Agronomic Research Institute to study the effect of time of planting on the occurrence of internal brown spot in the potato variety Arran Banner. Potato seedpieces were planted at approximately monthly intervals during the first year, while in 1958 at Lebanese Agronomic Research Institute they were planted at fifteen day intervals. The results of the experiments indicate that the intensity of internal brown spot in harvested tubers decreased with delayed planting dates. February plantings produced tubers with a high incidence of the disease (78 per cent) and the June plantings produced tubers having as little as 1 per cent internal brown spot. Yield of potatoes were found to decrease with delayed planting. June planting produced good quality tubers

which kept well for four months in storage while the early planted potatoes produced small-size tubers of poor quality and a high percentage of them sprouted while still in the ground.

Literature Cited

1. Ellison, J. Howard and Walter C. Jacob. 1952. Internal browning of potatoes as affected by date of planting and storage. Amer. Potato Jour. 29: 241-252.
2. Jones, H. A., B. E. Brown and G. V. C. Houghland. 1951. Plant nutrient deficiency symptoms in the potato. Hunger Signs in Crops. The American Society of Agronomy and the National Fertilizer Association, Washington, D. C.
3. Larson, R. H. and A. R. Albert. 1945. Physiological internal necrosis of potato tubers in Wisconsin, Jour. Agr. Res. 71 (11): 487-505.
4. Wolcott, A. R. and N. K. Ellis. 1956. Associated forms of internal browning of potato tubers in Northern Indiana. Amer. Potato Jour. 33: 343-357.

THE EFFECT OF HARVEST DATE AND RATE OF NITROGEN FERTILIZATION ON THE MATURITY, YIELD AND CHIPPING QUALITY OF POTATOES[1]

G. W. Hope, D. C. MacKay and L. R. Townsend

Introduction

It has been suggested (13, 20, 21) that the quality of potato chips may be affected by the maturity of the tubers from which they are made. Shallenberger (9) showed that color in chips made from mature potatoes was lighter than in chips made from immature tubers of the same variety. Smith (13) indicated that lengthening the growing season by earlier planting may improve chip color, whereas Akeley (1) reported that color of chips was influenced by date of vine removal.

Total solids, reducing sugars and free amino acids in the tubers have been found by Shallenberger (9) and by Habib and Brown (5) to collectively influence the browing of chips. Several workers (11, 14, 17) have reported variation in content of solids due to length of growing season, but the effect of maturity on the solids, sugars and amino compounds in tubers and on their chipping quality has not been demonstrated. Results obtained in experiments designed to investigate this effect are presented in this paper.

Materials and Methods

A range of maturities was obtained by using four levels of nitrogen, six harvest dates and two varieties of potato. A preliminary experiment in 1956 was set up in a complete factorial randomized block arrangement with three replicates. The main experiment, in 1957 was similar but the six harvest dates were included as split plots to permit more accurate examination of the harvest date factor. In both years P_2O_5 and K_2O were applied to all plots at the rate of 240 pounds per acre. Nitrogen applications were at the rates of 0, 80, 160 and 320 pounds per acre in 1956; in 1957 the 320 pound rate was reduced to 240 pounds per acre. All fertilizers were placed in a band under the seed piece by hand and covered with about one-half inch of soil. The varieties chosen were Kennebec, which matures relatively early and Sebago which requires a longer growing season. Standard cultural methods were followed. Foliage disease and insect damage were kept to a minimum with Bordeaux and D.D.T. sprays. The center 10 feet of a single row was harvested for yield data.

Tubers were harvested at ten-day intervals from mid-August to mid-October and the weight of Canada No. 1 potatoes was recorded. Maturity ratings were determined for each plot by making estimates of the percentage of dead leaves at each harvest date. Because a skewed distribution was obtained, percentages were transformed to equivalent angles for analysis of variance.

[1]Accepted for publication July 22, 1959.
Contribution No. 1016 from the Research Station, Canada Department of Agriculture, Kentville, N. S.

In 1956 tubers were stored at 45° F. for three months and conditioned for two weeks at 70° F. prior to chipping. In 1957 they were stored for a similar period but at 50° F. and were not conditioned. In both years, samples of 617 tubers were sliced, approximately 400 grams of randomly selected slices were rinsed in cold water to remove free starch, and the slices fried in hydrogenated vegetable oil* at 375° F. for 2½ minutes. The remainder of the slices were ground and suitable portions used in the determination of reducing sugar, dry matter and amino nitrogen. Reducing sugar content was obtained by the method of Townsend (19); dry matter was determined by drying ten grams of sample over night in a vacuum oven at 72° C., and amino nitrogen by the method of Yemm and Cocking (22). In the later determination the sample was extracted with 95 per cent ethanol and stored at —5° F. prior to analysis.

Chips were ground and the reflectance measured with a Photovolt model 610 Reflectance Meter, using the tristimulus green filter and a white enamel plaque as working standard. A photovolt reflectance reading of 25 or less was associated with unsatisfactory chip color.

Results

Rate of nitrogen application, date of harvest and variety were all found to produce highly significant differences in yield, maturity and chip color (Table 1). The summary of main effects (Table 2) showed that Kennebec outyielded Sebago, matured earlier and produced lighter colored chips. Similarly potatoes from plots receiving less nitrogen matured earlier and produced whiter chips. The harvest dates selected gave a wide range in maturity levels, and there were differences in chip color at different harvest dates but lightness of chip color was not associated with lateness of harvest. The highest yields were obtained at the fifth harvest date and at 160 pounds N per acre.

Reducing sugar content was found to increase with early harvesting, (Table 2). Amino nitrogen content increased as the rate of nitrogen increased (Table 2) in both varieties. Dry matter content was higher in the potatoes receiving no nitrogen and showed a slight tendency to increase with maturity. The coefficient for the correlation between maturity and dry matter content was +.4122 and is significant at the 1 per cent level.

A negative correlation, significant at the 1 per cent level, was found between chip color and reducing sugar content and also between chip color and amino nitrogen content (Table 3). An increase in the correlation coefficient was found when the three variables were considered in a multiple correlation, suggesting a complementary action between reducing sugar and amino nitrogen. Partial correlation coefficients indicated the reducing sugar content was more closely related to chip color in Sebago than in Kennebec. In neither case was the coefficient high enough to entirely account for all color developed.

The effect of maturity on chip color was determined by plotting the regression lines (Figure 1). In both varieties where 160 pounds of N was applied, chip color became lighter as maturity increased, but the lighter color did not occur at all levels of nitrogen.

*Primex B & C manufactured by Proctor and Gamble.

TABLE 1.—*Summary of variance analysis of potato maturity, yield and chip color.*

Source	Degrees Freedom	Variance Ratio		
		Maturity	Yield	Color
Varieties	1	162.00**	54.70**	39.72**
N. Treatments	3	49.70**	87.56**	15.42**
N x Varieties	3	3.54*	0.36	0.68
Harvest dates	5	266.00**	59.73**	4.13**
Varieties x dates	5	17.50**	5.05**	5.75**
N x dates	15	3.48**	2.62**	0.24
N x dates x varieties	15	3.76**	1.00	1.11

*Significant at probability of 5 per cent.
**Significant at probability of 1 per cent.

TABLE 2.—*Effect of variety, nitrogen level and harvest date on maturity, yield and chipping quality of potatoes.*

	Maturity (degrees)	Yield (bu/A)	Chip Color (per cent Reflectance)	Dry Matter (per cent)	Reduc. Sugar (per cent D.M.)	A. nitrogen (mg/100 gm.)
Varieties						
Kennebec	48.9	399	33.4	20.97	1.62	27.63
Sebago	29.5	321	22.0	20.71	2.42	21.96
L.S.D. (P.05)	3.1	22	1.1	0.30	0.11	3.03
Harvest Date						
First	2.8	244	28.5	20.16	2.17	19.40
Second	15.9	288	26.8	20.68	2.03	20.61
Third	27.5	377	30.2	21.34	2.05	30.57
Fourth	43.5	418	25.2	21.09	2.06	26.74
Fifth	66.4	428	24.3	21.16	1.98	23.40
Sixth	79.1	402	26.3	20.60	1.85	28.05
L.S.D. (P.05)	5.3	33	2.4	0.53	0.15	2.91
Nitrogen Application						
0	47.0	212	30.1	21.66	1.90	14.85
80	47.9	397	29.0	21.03	1.95	21.86
160	37.1	423	26.8	20.33	2.11	29.03
240	24.8	407	25.0	20.34	2.14	33.42
L.S.D. (P.05)	4.4	31	2.2	0.59	0.23	6.05

DISCUSSION

The term "maturity" as applied to potatoes, lacks precision but its approach is usually estimated by the degree of senescence evident in the potato tops, or, if the normal "season" of a variety is known, by the time from planting to harvest .

The extremely high variance ratios for the main effects (Table 1) suggest that maturity was accurately defined by the method of estimation

TABLE 3.—*Correlation and partial correlation coefficients—chip color studies.*

	Correlation			Partial Correlation	
	Kennebec	Sebago	Both Varieties	Kennebec	Sebago
Reducing sugar x chip color	—.38	—.52	—.45	—.42	—.51
Amino nitrogen x chip color	—.48	—.30	—.40	—.45	—.21
R. sugar x A. nitrogen x chip color	.56	.55	.78		

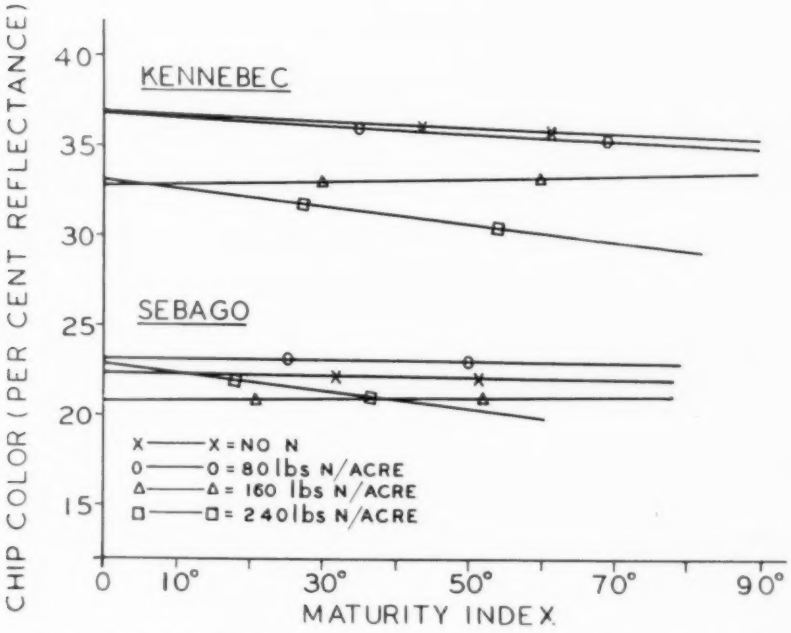

FIGURE 1.—Relationship between chip color and maturity index (per cent of dead leaves transformed to angular values).

used and is indicative of wide differences. The delay in maturity at the higher rates of nitrogen application is in agreement with the findings of Hawkins (6).

The maturity of the tubers was found to have a definite effect on the color of potato chips. This is in accordance with the suggestion of others (1, 9, 12, 20) and partly corrobrates the work on vine removal reported

by Terman *et al* (17). The normal trend is toward improved chip color from more mature potatoes. This trend may be reversed, however, by excessive use of nitrogen (Figure 1).

Potatoes receiving high rates of nitrogen were found to be richer in amino acids than potatoes of similar maturity from low nitrogen plots. Reducing sugar levels, contrary to the observation of Eastwood and Watts (4) were significantly affected by rate of nitrogen application, but differences were slight. Reducing sugars were higher in the less mature potatoes from the early harvests.

The multiple effect of amino acid and reducing sugar on chip color has been demonstrated (5, 9). In the present study the concentration of reducing sugar was the chief factor limiting color development in chips from potatoes grown at low rates of nitrogen fertilization. Reducing sugar levels were higher in less mature tubers and satisfactory chip color was consequently associated with mature tubers. At excessive rates of nitrogen application, however, color development appeared limited by amino acid concentration, and was less closely associated with the maturity of the tuber.

Chips made from Kennebec tubers were acceptable even when made from the most immature potatoes, and while there were significant differences in color, the differences were not of practical importance.

The yield response from 80 pounds per acre of nitrogen is greater than has been generally reported (16) and is no doubt due to the inherent low fertility of the soil at the experimental site. The further slight response up to 160 pounds per acre, while not significant, agrees with the results of other experiments (6, 7), and the decrease beyond that point may be partly due to a toxic effect on the young plants as these treatments had fewer hills per plot. The highly significant interaction of nitrogen x harvest dates suggests that nitrogen fertilization heavier than 80 pounds per acre may be detrimental to yield if the crop is to be harvested early.

Conclusion

The highest yields of tubers giving acceptable chip quality were found where potatoes receiving 160 pounds of nitrogen per acre were harvested when at least 80 per cent of the leaves had died.

Kennebec consistently outyielded Sebago, matured earlier and gave satisfactory chip color at all maturities and at all four levels of nitrogen fertilization.

Mature tubers of both varieties gave chips of lighter color than immature potatoes. The effect of maturity on chip color appeared to be due to higher reducing sugar levels in immature tubers.

Potatoes from plots receiving higher rates of nitrogen had greater concentrations of free amino acids and gave darker chips than did potatoes receiving nitrogen at 80 pounds per acre.

Summary

Maturity of potatoes (as measured by degree of diedown of tops) was found to be more advanced in potatoes grown at low levels of nitrogen fertilization. Chip color improved as potatoes matured, but rate of nitrogen

application exerted an influence on chip color which was independent of its effect on maturity. Yields increased with length of growing season, and 160 pounds of N per acre gave the highest yield.

Literature Cited

1. Akeley, R. V., F. J. Stevenson and C. C. Cunningham. 1955. Potato variety yields, total solids and cooking quality as affected by date of vine killing. Amer. Potato Jour. *32*: 304-313.
2. ————, ———— and D. Merriam. 1955. Effects of planting dates on yields, total solids and chipping qualities of potato varieties. Amer. Potato Jour. *32*: 441-447.
3. Denny, F. E. and N. G. Thornton. 1940. Factors for color in the production of potato chips. Contrib. Boyce-Thompson Inst. 11: 291-303.
4. Eastwood, T. and James Watts. 1956. Effects of nitrogen fertilization upon chipping quality—chip color. Amer. Potato Jour. 33: 187-189.
5. Habib, A. T. and H. D. Brown. 1956. Factors influencing color in potato chips. Food Technol. 10: 332-336.
6. Hawkins, A. 1956. Response of potatoes to fertilizer nitrogen in the northeast. Amer Potato Jour. 33: 226-233.
7. Odland, T. E. and J. E. Sheehan. 1956. The response of potatoes to different amounts and ratios of nitrogen, phosphoric acid and potash when grown in continuous culture. Amer. Potato Jour. 33: 22-27.
8. Salunkhe, D. K., E. J. Wheeler and S. T. Dexter. 1954. The effects of various environmental factors on the suitability of potatoes for chip making. Agron. Jour. 46: 195-199.
9. Shallenberger, R. S. and O. Smith. 1955. Browning reaction in potato chips. Amer. Potato Jour. *32*: 428-430.
10. Sheehan, J. E. and T. E. Odland. 1956. A quarter century of potato trials in Rhode Island. Amer. Potato Jour. 33: 161-165.
11. Smith, O. and L. B. Nash. 1942. Potato quality. V. Relation of time of planting, time of harvest and fertilizer treatment to composition and cooking quality. Jour. Amer. Soc. Agron. 34: 437-451.
12. ————. 1955. How to grow and store potatoes for the chip industry. Amer. Potato Jour. *32*: 265-268.
13. ————. 1957. Potatoes and NPCI Research.. Natl. Potato Chip Inst. Proc. Prod. & Tech Div. Meeting 1956, 2-5.
14. Stevenson, F. J., R. V. Akeley and J. G. McLean. 1954. Potato utilization in relation to variety (heredity) and environment. Amer Potato Jour. 31: 327-340.
15. Stultz, R. E. and R. H. Burris. 1943. Factors influencing oil content of potato chips. Food Indust. 15: 1146-7.
16. Terman, G. L., A. Hawkins, C. E. Cunningham and R. A. Strucktemeyer. 1951. Rate, placement and source of nitrogen for potatoes in Maine. Me. A.E.S. Bul. 490.
17. ————, C. E. Cunningham and M. Goven. 1952. Effect of date and method of kill on yield, specific gravity and other quality factors of Maine potatoes. Amer. Potato Jour. *29*: 279-289.
18. ————, M. R. Covell and C. E. Cunningham. 1957. Effect of size of plot, experimental design and replication on efficiency of potato fertilization experiments. Aer. Potato Jour. 34: 59-67.
19. Townsend, L. 1955. Reducing sugars in potatoes. Can. Fd. Indust. *26*: 1-2.
20. Wright, R. C., and T. M. Whiteman. 1948. Comparative chipping quality of thirty-three varieties of potatoes. Potato Chipper 7: 40-1.
21. ———— and ————. 1951. Varieties and handling of potatoes for chip manufacture .Potato Chipper 10: 32-3.
22. Yemm, E. W., and E. C. Cocking. 1955. Determination of amino nitrogen with ninhydrin. Analyst 80: 209-213.

A STUDY OF POTATO HARVESTING AT TULELAKE, CALIFORNIA[1]

J. R. TAVERNETTI[2] AND K. G. BAGHOTT[3]

In recent years potato growers throughout the United States have become more interested in bulk handling potatoes. This interest expressed by potato growers prompted the study in which a comparison of the tuber damage by both hand pick-up and mechanical harvesting methods were made. Sparks (3) at Idaho reported as much as 50 to 75 per cent loss of crop due to mechanical damage in potato harvesting and handling operations. These losses usually result in lowering of potato grade and increased storage rot and shrinkage. Hardenburg (2) showed in his studies on the Cleveland markets that mechanical bruising was the most serious defect on that market.

"Potato growers are mechanizing the harvesting of potatoes in order to reduce the cost of harvesting and handling, reduce the amount of labor and arduous nature of the work, increase the capacity of equipment and facilities and improve the handling of the potatoes and thus increase the general quality and salability of the crop". (1)

This report does not consider the cost of either mechanical harvesting or the hand pick-up method. Neither does it include any comparison of the cost of either operation.

PROCEDURE

In the three years 1953 to 1955, studies were conducted in the Tulelake area of Siskiyou and Modoc Counties to determine the amount of injury to potatoes during harvest. These studies were made during October, which is the main time for harvest in that area. Both hand and mechanical harvesting were included.

Hand harvesting consisted of digging with a conventional digger and then using hand labor to pick the potatoes off the ground and place them in stub stacks (Figure 1). Two row diggers were generally used but attachments on the rear combined the potatoes into a single windrow. Twenty to 30 pickers were employed for each two row digger. The stubs, weighing from 55 to 60 pounds, were loaded by hand onto flat bed trucks and hauled to specially constructed storage houses. There they were emptied into the hopper of a conveyor that dropped the potatoes onto piles 8 to 10 feet high.

MATERIALS AND METHODS

Mechanical harvesting was of two types, direct and indirect. With the direct type, the potatoes were dug and loaded into a truck in one operation. (Figure 2). With the indirect type, the potatoes were first dug with a conventional digger and then picked up from the surface of the ground and loaded into a truck. Three different makes of harvesters were used but all were of the same general type. They consisted of a series of conveyors

[1]Accepted for publication June 1, 1959

[2]Lecturer in Agriculture Engineering and Agriculture Engineer in Experiment Station, University of California, Davis, Calif.

[3]Farm Advisor and Agriculturist, University of California, Tulelake, Calif.

FIGURE 1.—Picking potatoes off the ground and placing them in stub sacks during hand harvesting at Tulelake.

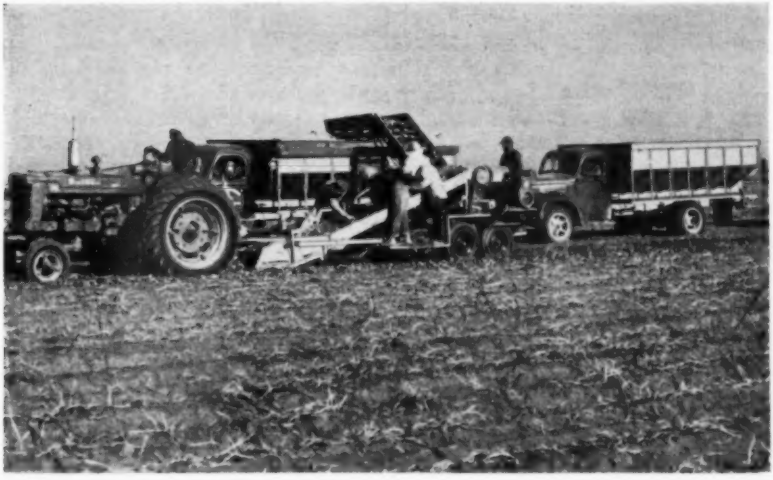

FIGURE 2.—A direct type mechanical potato harvester in operation at Tulelake.

which elevated the potatoes from the ground into a truck. Persons riding on the harvester picked clods, vines and other foreign material from the conveyors. The number of persons on the harvesters varied from 6 to 10. The harvesters were operated at speeds varying from ⅔ to 2 miles per hour, depending upon the field conditions.

The trucks were equipped with beds having bottoms that sloped towards a conveyor about 2 feet wide in the center. This conveyor ran the length of the bed and extended several feet out through an opening in the rear. At the storage sheds a motor drive was attached to the conveyor and the potatoes unloaded into the hopper of the elevating conveyor.

Field Conditions: The soil was mostly a muck type with the top several inches dry and medium moisture underneath. The fields in general were relatively cloddy but this varied with different fields and within the same field. All vines were dry and as many as possible removed by roto beating.. The yields varied with different growers from about 150 to 350 sacks per acre. They averaged about 250 sacks. Most of the potatoes were relatively mature.

Observations for Damage: Samples of potatoes were taken at three different stages of the harvesting operations and checked for damage. With hand harvesting, the samples were taken from the stub sacks in the field, from the stub sacks on the truck at the storage shed, and from the bulk potatoes in the storage bins. With the mechanical harvest samples were taken from the harvester discharge into the truck, from the truck discharge at the storage shed, and from the storage bins. The damage was divided into two types, cut or bruised, and skinned. Any damage, regardless of the amount, was counted. In addition to checking potato damage, the amount of clods in the potatoes was checked with the mechanical harvesting.

Results

Table 1 shows the average potato damage with the two methods of harvesting for all the farms studied during the three years. On the 13 farms using hand harvest, the total damage averaged 51 per cent, of which 14 per cent was cutting or bruising, and 37 per cent skinning. Approximately one-third of the total damage occurred in digging, another one-third in loading and hauling the stubs, and a third in unloading the stubs and conveying the potatoes into the storage bins. On the 18 farms using mechanical harvesters, the total damage averaged 37 per cent, of which 12 per cent was cutting or bruising, and 25 per cent skinning. Approximately two-thirds of the damage occurred in the harvesting, and one-third in unloading the trucks and conveying the potatoes into the storage bins. Very little damage occurred in the trucking. There was no correlation between the amount of damage and the type or make of harvester.

Table 2 shows the type of damage to the potatoes with the two methods of harvesting. Most of the damage was slight and medium skinning. The severe damage (badly skinned, cut and bruised) which probably would affect the marketing of the potatoes totalled 15 per cent with hand and 17 per cent with mechanical harvesting.

The amount of clods harvested with the potatoes varied over a wide range. It depended upon the soil conditions, speed of operating the harvester, and the number of pickers on the harvester. The percentage by number going into the trucks ranged from 4 to 41 per cent with an average of 18 per cent. The percentage at the truck discharge ranged from 2 to 36 per cent, with an average of 17 per cent. The percentage in the storage bins ranged from 1 to 10 per cent, with an average of 5 per cent. The

TABLE 1.—*Damage to potatoes at different stages of harvesting.*

Method of Harvest and No. of Farms	Stage of Harvest	Damage—Per cent		
		Cut and Bruised	Skinned	Total
Hand 13	Stubs[1] in field	6	9	15
	Stubs on truck at storage house	9	23	32
	In storage bins	14	37	51
Mechanical 18	Harvester discharge into truck	7	17	25
	Truck discharge at storage house	8	19	27
	In storage bins	12	25	37

[1]Partly filled burlap sacks

TABLE 2.—*Types of damage to potatoes during harvest at different stages of handling.*

Method of Harvest and No. of Farms	Stage of Handling	Damage—Per cent					
		Slightly Skinned	Medium Skinned	Badly Skinned	Cut	Bruised	Total
Hand 7	Stubs[1] in field	9	1	0	3	2	15
	Stubs on truck at storage house	19	3	1	3	5	31
	In storage bin	27	9	4	3	8	51
Mechanical 8	Harvester discharge into truck	17	4	1	3	7	31
	Truck discharge at storage house	18	4	3	3	7	35
	In storage bins	22	5	3	3	11	44

[1]Partly filled burlap sacks.

reduction in storage was due mainly to having one or two persons at the storage shed picking clods off the conveyor going into the bins.

CONCLUSIONS

There was practically no difference in the amount of serious injury between hand and mechanical harvesting by the time the potatoes were in storage. There was less injury in the field with the hand method but rough handling of the stubs in loading onto the trucks and in emptying at the storage shed, caused a considerable increase. More damage than necessary occurred with both methods in conveying the potatoes into the storage bins. Reducing the drop into the conveyor hopper, better padding in the hopper, and keeping the drop from the discharge end to a minimum, would help to reduce this damage.

LITERATURE CITED

1. Greene, R. E. L., L. J. Kushman, J. S. Norton, H. C. Spurlock. 1954. Mechanical harvesting and bulk handling of potatoes in Florida and Alabama.
2. Hardenburg, E. V. 1937. Grade analysis of potatoes on Cleveland market. Am. Potato Jour. 14: 107-116.
3. Sparks, Walter C. 1954. Injury to Russet Burbank potatoes by different harvesting machines.

NEWS AND REVIEWS

CHEMICALS AND FOODS

EZRA TAFT BENSON

Our food supply in the United States is the safest, cleanest, and most wholesome in the world. The Department of Agriculture takes pride in the part it has played in making this true.

The Department considers that the safety of the Nation's food is its first responsibility in carrying out assignments from the Congress. This principle guides USDA research programs and regulatory and service activities pertaining to foods and to the use of chemicals in food production and distribution.

The Department intends to continue and intensify its efforts to insure that American consumers get the foods they need and want, in adequate quantities at a reasonable price, and that these foods continue to meet the highest standards of nutritional quality and wholesomeness. It strongly endorses the *safe* use of *carefully tested* chemicals as required to maintain the excellence, variety, and economy of the foods we eat.

Role of Chemicals in Food Production

A wide variety of chemicals are used today in all phases of food production, processing, and marketing. They include chemical fertilizers, insecticides, and weed killers . . . antibiotics, antiseptics, and preservatives . . . feed additives, fumigants, fungicides . . . and others.

These chemicals are as essential for efficient production of foods on the farm as are tractors, improved varieties of crops, and better breeds of livestock. They play as great a part in assuring consumers a continuing supply of nutritious and appetizing foods as do our modern methods of food processing and marketing.

We cannot continue to produce adequate amounts of safe and wholesome foods without chemicals. Abandoning their use on farms and in the food industry would result in immediate decline in the quantity and overall quality of our food supply and cause a rapid rise in food prices paid by consumers.

On our farms, chemicals enable us to produce the great variety of foods people want in the tremendous quantities needed. They also give indispensable protection to the natural excellence of these foods against the ravages of pests and diseases. In large part because of chemicals, American consumers enjoy fruits, vegetables, cereals, meat, poultry products, and milk of unexcelled quality and freedom from contamination.

In our food factories and in trade channels, chemicals help to improve sanitation and maintain quality. They make possible many of our modern convenience foods, and in many other ways they aid in furnishing the bountiful, nutritious supply of good things to eat that we enjoy today.

The use of chemicals in foods themselves is as old as the practice of preserving meat with salt . . . and as new as the addition of thiamine to bread.

Government Responsibility for Food Safety

For more than half a century — since passage of the original Food and Drug Act and the Meat Inspection Act — the Federal Government has had national responsibility for insuring that foods in interstate com-

merce are safe, pure, wholesome, and produced under sanitary conditions, and that all such products are honestly and informatively labeled and properly packaged.

Effective enforcement of these laws, in which the Department of Agriculture has an essential part, is the foundation for the widespread and soundly based confidence consumers have in the foods they buy.

USDA, the State experiment stations, and industry research develop methods for the safe use of chemicals by farmers and the food industry. Educational programs of the Department and the State Extension Services, geared with this research, provide field guidance to farmers and others in the safe and economical use of approved chemicals.

Legal responsibility for insuring the safety and wholesomeness of our national food supplies is shared by the Department of Agriculture and the Department of Health, Education and Welfare, and by their counterparts in every State.

USDA and DHEW work together in determining and evaluating the safe use of chemicals by farmers, processors, and distributors of food products. When chemicals are not properly used, and foods are found to be contaminated or otherwise unsafe, DHEW's Food and Drug Administration and USDA's meat and poultry inspection services seize or condemn the products.

In every way possible, Department actions are aimed to assist growers, processors, and distributors in producing and marketing products that meet all the requirements of law regarding safety and wholesomeness. USDA is continuing today, as for many years past, to withhold approval of the use of chemicals that do not meet these requirements.

Federal Meat and Poultry Inspection

The Department of Agriculture has responsibility in the Federal Government for inspection of fresh meat and poultry and processed meat and poultry products to assure that they are wholesome, free from disease and adulteration, and accurately labeled.

This inspection applies to plants that prepare meat or poultry products for interstate or foreign commerce. It requires, first of all, Federal approval of the construction, equipment, processing procedures, and sanitation of each plant. Inspection of animals and birds in the plants begins in the holding pens or receiving rooms and extends to the final product.

All formulas used for prepared meat and poultry products must have prior USDA approval. Cereals, dried milk, spices, fats, water, curing chemicals, and all other ingredients in such products must meet specific standards of safety and quality, and must be used in approved quantities. Rigid controls are maintained also to insure adequate cooking, cooling, and storage facilities required to produce safe, high-quality products. Labels to be applied to containers or packages of processed meat or poultry products must be approved before use.

For these inspection activities, USDA maintains chemical and biological laboratories to furnish inspectors with the information they need to make proper decisions in their daily work.

Standards for meat and poultry products are developed and enforced to assure the purchaser that he is receiving the kind of product he is entitled to expect from the label.

Responsibility for Other Foods

Final jurisdiction over the safety and wholesomeness of foods moving interstate other than meat and poultry products inspected by USDA is the responsibility of the Department of Health, Education, and Welfare. This responsibility is carried out on the basis of compliance by food producers and distributors with standards established by the Food and Drug Administration. Products found not to comply with these standards are subject to seizure. State and local governments of course have similar jurisdiction over foods in intrastate and local commerce.

Pesticide Regulation

The Department of Agriculture is responsible for registering and safe labeling of insecticides, fungicides, rodenticides, chemical weed-killers, and other pesticides, including germicidal chemicals for use on inanimate surfaces. Before a product is registered, a list of its ingredients, directions for safe use to obtain the results claimed, and precautions necessary in handling must appear on the label. All label statements must be both factual and clear.

USDA's registration of pesticides and instructions for their use appearing on the labels requires determinations that use of the product according to instructions is safe and will not result in harmful residues.

Under current legislation, the Food and Drug Administration establishes residue tolerances or exemptions from tolerances for pesticides. USDA has responsibility for determining whether a proposed pesticide use will leave residues on food or feed.

Recommendations by USDA for the safe and effective use of agricultural chemicals by farmers are based on determination that the recommended practices will not result in health hazards due to contamination of foods.

Pest Quarantine and Eradication

The Department's work on prevention, control, and eradication of crop and livestock pests and diseases — including quarantine programs designed to keep foreign pests from entering this country and to halt the spread of insects and diseases within our borders — also contribute to both the quality and the quantity of our food supplies.

These vital programs protect foods by eliminating diseases, insects, and other causes of contamination and unwholesomeness at their source, before they have a chance to affect crops and livestock in the market.

Grading Services

Still other phases of USDA activities that promote the high quality of our food supplies include the development of commercial grade standards and the provision of grading services on a voluntary basis for agricultural products to be sold under these standards.

Research Programs

Agricultural and food chemicals in use today are the products of many years of research, in which the effect of these chemicals on the safety of our food supplies and the health of consumers has been a prime consideration. This research — conducted by the Department of Agriculture, the State Agricultural Experiment Stations, and the chemical and food industries — is continuing on a substantial scale.

Its objectives are not only to develop safe and effective chemicals but also to discover non-chemical means, including various biological agents

and techniques, for assuring efficient production and marketing of wholesome food in adequate quantities.

Many chemical control measures now available for use cannot be recommended because of inadequate information on the significance for human health of the residues they may leave in food products. Some insecticides and other chemicals now recommended, if used without proper safeguards, can leave residues that present actual or possible hazards.

To meet these problems, an intensified educational program is needed to insure proper use of present chemicals. Further research is required to develop (1) new methods to control insects and other pests that do not involve the use of chemicals, and (2) safe chemicals for pest control and improved methods for their application and use — for example, with specific attractants to gain greater effectiveness with smaller dosages.

Biological methods offer the best chance for control of destructive insect pests by non-chemical means. In a few cases — as in the recent campaign against the screwworm pest of livestock in the Southeast, where radioactively sterilized screwworm flies were used — biological methods have proved successful. But the biological agents we have discovered and learned to use so far cannot begin to solve our pest-control problems. Farmers must still depend primarily on safe, effective, and economical chemicals to produce the quantity and quality of crops and livestock necessary for the Nation's needs.

It Pays to Use Chemicals Carefully

Farmers, processors, and distributors all have a stake in the proper use of agricultural and food chemicals. Their concern with the safety and wholesomeness of the food supply is identical with that of consumers.

Years of experimentation and experience show conclusively that the most profitable, as well as the safest, way to use chemicals in producing, processing, or marketing a food is to *follow instructions on the label.*

Feeding experiments by the Department show clearly, for example, that there is no advantage to cattle feeders in using stilbestrol in quantities greater than recommended. The full value of this additive in the saving of food can be realized without resorting to overdoses.

The same is true in using other chemicals in food production and marketing. Before a chemical can be placed on the market the manufacturer must demonstrate that when used as prescribed on the label, it will do the job claimed for it and will not leave a harmful residue.

Growers have still another reason to use chemicals exactly as directed. If harmful residues are found on their products it means that they cannot be marketed.

A continuing campaign of education for all who use agricultural chemicals is now being intensified by the Federal and State Extension Services. A new series of leaflets from the Department of Agriculture is in preparation. These and similar materials from the States are scheduled for wide distribution to growers and handlers of foodstuffs.

Consumers, as well as farmers and the food industry, have a vital stake in the safe use of chemicals in food production, and in the research and regulatory programs of our Federal and State governments that assure wholesome, high-quality foods in economical abundance. Only wide public understanding of these facts can provide the necessary basis for continued supply of good foods we can enjoy in safety.

1960 MEETING, POTATO ASSOCIATION OF AMERICA

The joint meetings with the American Phytopathological Society will be held this year at the American Baptist Assembly at Green Lake, Wisconsin, August 28-31. A potato tour for those interested will start things off Saturday, the 27th, with a visit to several research plots at the Hancock Branch Experiment Station. A tour of the central Wisconsin potato growing area to observe harvest and other operations will continue Sunday prior to going on to the Center for registration. A noon banquet is planned for Monday, the 29th. The facilities at the Center are very adequate and a large attendance is anticipated. Meals and lodging for families will be available, and recreation at the camp is extensive and diversified. Special tours and other activities are planned for those not actually attending the sessions, *i.e.*, wives, children, and friends. Complete details will be announced soon concerning transportation, reservations, and the entire program for the different sessions.

HENRY DARLING

BOOK REVIEW

PLANT PATHOLOGY: THE DISEASED PLANT, edited by J. G. Horsfall and A. E. Diamond is the first of a 3-volume advanced treatise on plant pathology. This volume emphasizes the diseased plant's reaction to the pathogen and the mechanisms by which the pathogen interferes with the normal functioning of the plant under the Chapter headings: The Diseased Plant, How Sick is the Plant?, Tissue is Disintegrated, Growth is Affected, Reproduction is Affected, The Host is Starved, Water is Deficient, Alteration of the Respiratory Pattern in Infected Plants, Histology of Defense in Plants, Physiology and Biochemistry of Defense, Hypersensitivity, Predisposition and Therapy. Two chapter are devoted to the history and the scope and contributions of plant pathology.

This book which deals with the principles of plant pathology, is written by 19 well qualified plant pathologists from 6 countries. It is of value as a text and reference book for advanced students, teachers and research workers in plant pathology and related fields. Each chapter contains a wealth of information compiled by one or more authorities who have summarized and evaluated the published material. Of particular value are the selected references found at the end of each chapter.

Academic Press Inc., 111 Fifth Ave., New York 3, N. Y. and 40 Pall Mall, London, S.W.1., 675 pp., $22.00.

B. H. DAVIS, *Chairman, Department of Plant Pathology, Rutgers Univ.*

TOTAL POTATO STOCKS ON JANUARY 1, 1960

Total storage stocks of potatoes held by growers and local dealers on January 1, 1960 amounted to 97.5 million hundredweight, according to the Crop Reporting Board of the United States Department of Agriculture. These holdings were 10 per cent below the 108.3 million hundredweight held on January 1, 1959, but 4 per cent above the 1949-1958 average stocks of 93.4 million hundredweight. The current January 1 stocks are 59.0 per cent of the fall crop which compares with the 1958 crop holdings

of 59.2 per cent on hand January 1, 1959, and the 1949-1958 average of 60.0 per cent.

Total stocks in the 8 *Eastern States* on January 1, 1960 were 37.4 million hundredweight — about 13 per cent below the holdings of 43.0 million hundredweight for this region on the same date a year earlier. In the 9 *Central States*, January 1 holdings this year amounted to 22.1 million hundredweight — 5 per cent below the stocks of 23.3 million hundredweight estimated for this region a year ago. In 9 *Western States*, fall potatoes in storage on January 1, 1960 totaled 38.0 million hundredweight, which was 9 per cent below the holdings of 42.0 million hundredweight for these States a year earlier.

Disappearance of storage potatoes during December 1959 was the second highest of record in the past 10 years, having been exceeded only in December 1958. Estimated December disappearance was 20.2 million hundredweight compared with 21.4 million hundredweight in December 1958, and the 1949-1958 average disappearance of 16.8 million hundredweight. Movement of potatoes to market during December from the 1959 fall crop, as indicated by rail and truck unloads at 38 cities, was substantially above the same period of 1958. Movement to chippers in the 20-city local market area was moderately above 1958. The aggregate quantity of fall potatoes processed for other food uses during December 1959 was also indicated to have been larger than a year earlier, but movement to starch factories was below the same period of 1958.

Disappearance from the 1959 crop of fall potatoes from time of harvest to January 1, 1960, the second largest of record in the past 10 years, amounted to 67.6 million hundredweight, compared with 74.6 million hundredweight during the same period from the larger 1958 fall crop, and the 1949-1958 average of 62.2 million hundredweight. Disappearance covers sales for all purposes as well as quantities used to date on farms where grown and those lost through shrinkage, decay, and waste.

The estimates of total stocks represent all potatoes held by growers and dealers in or near producing areas in the 26 fall producing states. They include quantities to be sold or used for table stock, starch, other processing, feed for livestock, seed for the succeeding crops, and for feed, seed, and food on farms where grown. The stocks estimates also include potatoes that will be lost through shrinkage, decay, and dumping after January 1.

Sales of fall potatoes for all purposes during the past two seasons have averaged about 86 per cent of production. The balance of the crop has been used on farms where grown for seed, household use and livestock feed, and lost through shrinkage.

1960 Winter Crop Estimates

The 1960 *winter* potato production is estimated at 3,464,000 hundredweight. This is about 5 per cent above the forecast on December 1 but 14 per cent below the 1959 winter potato production of 4,005,000 hundredweight and 17 per cent less than the 1949-1958 average of 4,190,000 hundredweight. Harvest of the winter potato crop in *California* has been progressing at a moderate rate in the southern San Joaquin Valley and in the Perris-Hemet districts.

Potatoes harvested in Kern County are of excellent quality with sizes

running about normal. More than the average number of potatoes are of small sizes in Madera, Fresno, Tulare, and Kings Counties due to an unusually heavy set of tubers.

Rains in *Florida* during November delayed some plantings in Dade County; replanting is now generally complete. Harvest is now active in the Everglades with yields lighter than expected. In the Balm area, harvest is expected to begin about January 10-15. Relatively light yields will be harvested from the cold-damaged acreage. The crop in the Fort Myers-Immokalee area is growing nicely.

Growers in the *late spring* potato areas indicate intentions to plant 146,500 acres in 1960; about 6 per cent more than the 138,800 acres planted in 1959.

California, the largest late spring producing State, reported intentions to plant 51,500 acres, about 13 per cent more than in 1959. Plantings are about half complete in the Edison district of Kern County with scattered plantings underway in several other early Kern County districts.

Growers in 4 other States also reported intentions to plant more acreage of late spring potatoes than in 1959. These are the 8 northeastern counties of North Carolina, Alabama, Louisiana and Texas. All other States reported intentions the same or below those of last year.

—*U.S.D.A. Crop Reporting Board*

14th NATIONAL CONFERENCE ON HANDLING PERISHABLE AGRICULTURAL COMMODITIES

The 14th National Conference on Handling Perishable Agricultural Commodities will be held at Purdue University, Lafayette, Indiana, February 29 through March 3, 1960. The objectives of the conference are to bring together those persons interested in striking directly at preventable losses and damages in the transportation of perishable fruits and vegetables.

This conference is sponsored by Purdue University, the Association of America Railroads, and the American Railway Development Association with the cooperation of Railway Inspection Agencies and the United States Department of Agriculture.

Programs for this conference may be obtained by writing the Horticultural Department, Purdue University, Lafayette, Indiana.

INTERNATIONAL POTATO RESEARCH PROJECTS

The titles of some important foreign potato research projects were not submitted to Dr. Larson last year for publication in the American Potato Journal. We would like to have this list of projects as complete as possible so that our members will know what research projects are underway throughout the world and who is conducting them. We will publish the titles of the projects not included in the first listing if the number received warrants it. Please send, as soon as possible, the titles of the projects, the particular problems involved, the names of the research workers involved and the name and address of the institute, university or other agency responsible for the research, to Dr. Russell Larson, Department of Plant Pathology, University of Wisconsin, Madison, Wisconsin.

IT PAYS TO BE HIDDEN HUNGER CONSCIOUS

Plants, like people, can suffer from hidden hunger — the period between the time they are in good health and in bad health. This is an insidious time because nothing looks wrong. The plant seems to be healthy — or certainly shows no signs of hunger. And then — almost suddenly, it seems — the plant crosses a point of no return as far as its finest yield and quality are concerned. Outward signs may never show — except in the yield. It's an insidious thing. Hidden Hunger! A problem requiring careful diagnosis and management that is always hunger conscious.

AMERICAN POTASH INSTITUTE, INC.

SERVING AGRICULTURE FOR OVER TWO DECADES

1102 Sixteenth St., N. W. Washington 6, D. C.

Member Companies: American Potash & Chemical Corporation • Duval Sulphur & Potash Company • Potash Company of America • Southwest Potash Corporation • United States Potash Company Division of United States Borax & Chemical Corporation

Top the Market with Lockwood Graders

GERING, NEBR.

LOCKWOOD!!

★ A SYMBOL OF SERVICE

★ A SIGN OF QUALITY

SEW UP THE PROFITS

with a **LOCKWOOD** Automatic Sewing Machine

The ever increasing trend to pre-package produce demands the finest and most economical in pre-pack machinery. Choose the best!! Choose LOCKWOOD!!

MODEL

LOCKWOOD GRADERS

Gering, Nebr. (HOME OFFICE) Dealers in principal potato areas.

FACTORY STOCKS AT:

PRESQUE ISLE, ME.
SIX LAKES, MICH.
ANTIGO, WISC.
RUPERT, IDAHO
GRAND FORKS, N. D.
NIEUW AMSTERDAM.
QUINCY, WASH.
TULE LAKE, CALIF.
MONTE VISTA, COLO.
GILCREST, COLO.
HEREFORD, TEXAS
HASTINGS, FLA.
BAKERSFIELD, CALIF.

Get higher yields — better chipping quality with Sul-Po-Mag

Protect your income two ways! Get bigger potato yields and excellent chipping quality with fast acting, water soluble Sul-Po-Mag.* Double sulphate of potash-magnesia (Sul-Po-Mag) in your soil supplies magnesium needed for chlorophyll formation. That's why Sul-Po-Mag helps your plants produce more potatoes of full growth and maturity.

It also contains potash in the sulphate form rather than the chloride form. The sulphate form reduces the water content of the potato increasing desirability as a product for french friers and chippers.

You can market more potatoes. More markets are open to your potatoes.

Magnesium Deficiencies

Special soil problems connected with potato growing make magnesium a critical element. Potatoes are usually grown on light, moderately acid soils — naturally low in magnesium.

Since magnesium deficiencies aren't visible until major damage has been done to the yields, regular program of soil testing and tissue testing should be followed to be sure that adequate supplies of magnesium are being added to the soil for maximum growth results. Sul-Po-Mag, unlike dolomitic limestone, does not change the soil acidity . . . therefore its use can not increase the danger of scab.

Producers of Living Minerals

MINERALS International CHEMICALS

And, Sul-Po-Mag is granular. That means it dissolves at a controlled rate all season long to give growing plants the nutrients when they need them. Sul-Po-Mag provides proper balance between ready availability and lasting quality.

Protect your yields

Lack of magnesium can lower your yields as much as 100 bushels per acre. Be sure you aren't losing income that your work and soil could bring you. Test for magnesium. Correct deficiencies by getting Sul-Po-Mag in the mixed fertilizers you buy. Talk to your county agent, talk to successful growers in your area, talk to your fertilizer dealer. Sul-Po-Mag in mixed fertilizer delivers the kind of results they'll be glad to tell you about.

Trademark, International Minerals & Chemical Corporation

S·P·M PREMIUM

Quality fertilizer containing a combination of readily available magnesium and sulphate of potash obtained from Sul·Po·Mag (DOUBLE SULPHATE OF POTASH & MAGNESIUM)

Look for this identifying seal of approval when you buy. It's your assurance of extra-value fertilizer.

INTERNATIONAL MINERALS & CHEM. CORP.
Dept. APJ-43, Skokie, Ill.

Please send me a free copy of your "Magnesium" booklet which discusses magnesium and Sul-Po-Mag for specific crops.

Name .....

Route .....

Town ..... State .....

43-59

AGRICULTURAL CHEMICALS DIVISION

INTERNATIONAL MINERALS & CHEMICAL CORPORATION

Administrative Center: Skokie, Ill.